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Draft Oil Spill Research Strategy

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Acronym List

ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BAA	Broad Agency Announcement
BTEX	benzene, Ttluene, ethylbenzene, and xylenes
BFT	Baffled Flask Test
BOEMRE	Bureau of Ocean Energy Management
CDC	Centers for Disease Control and Prevention
CDOM	Chromophoric Dissolved Organic Matter
CEWAF	Chemically Enhanced Water Accommodated Fractions
CO_2	carbon dioxide
CRRC	Coastal Response Research Center
DFO	Department of Fisheries and Oceans (Canada)
DHHS	Department of Human and Health Services
DHS	Department of Homeland Security
DMP2	Dispersant Mission Planner 2
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOSS	dioctyl sodium sulfosuccinate
DOT	Department of Transportation
DWH	Deepwater Horizon
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EROD	ethoxyresorufin-*o*-deethylase
ERO3S	EPA Research Object-Oriented Oil Spill model
ETV	Environmental Technology Verification
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FWS	Fish and Wildlife Service
GIS	Geographic Information Systems
GLNPO	Great Lakes National Program Office
GRI	Gulf of Mexico Research Initiative
IATAP	Interagency Alternative Technology Assessment Program
ICCOPR	Interagency Coordinating Committee on Oil Pollution Research
LCA	Life Cycle Assessment
MARAD	Maritime Administration
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NIEHS	National Institute of Environmental Health Sciences

NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Science Technology
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRC	National Research Council
NRDA	National Resources Damage Assessment
NRMRL	National Risk Management Research Laboratory
NRPC	National Resource Program Center (NPS)
NRT	National Response Team
NSF	National Science Foundation
OEM	Office of Emergency Management
OHHI	Ocean and Human Health Initiative (NOAA)
OSHA	Occupational Safety and Health Administration
OSLTF	Oil Spill Liability Trust Fund
OIS	Oil Identification System
OMB	Office of Management and Budget
OPA-90	Oil Pollution Act of 1990
ORD	Office of Research and Development
OSC	On-scene Coordinator
OSWER	Office of Solid Waste and Emergency Response
PAH	polycyclic aromatic hydrocarbons
PBPK	Physiologically-based pharmacokinetic
PHMSA	Pipeline and Hazardous Materials Safety Administration
PM	Particulate Matter
R4-EDT	Region 4 Environmental Decision Toolkit
ReVA	Regional Vulnerability Assessment
SAMHSA	Substance Abuse and Mental Health Services Administration
SMART	Special Monitoring of Applied Response Technologies
TIC	Total Inorganic Carbon
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WAF	Water Accommodated Fractions

Executive Summary

The Environmental Protection Agency's (EPA) Oil Spill Research Program has been conducting research since it was authorized under in the Oil Pollution Act of 1990 (OPA-90). The Deepwater Horizon (DWH) spill highlighted the need for innovative spill response technologies and raised questions relative to the use of dispersants as well as acute and chronic health effects for spill response workers and the public

To respond to these research issues, the EPA has developed a research strategy for FY12 through FY15, putting forth a comprehensive research approach on potential human and environmental risks from oil spills and the application of dispersants, surface washing agents, bioremediation agents, and other mitigation measures. The goal of this research program is to provide environmental managers with the tools, models, and methods needed to mitigate the effects of oil spills in all environments, emphasizing the coastal and inland environments.

The proposed research is composed of four themes and will incorporate research to:

- Develop a better understanding of the impacts of oil spills and dispersants application on the environment.
- Develop a better understanding of the shoreline, coastal, and inland environment impacts of oil spills, including non-petroleum oils.
- Develop innovative technologies to mitigate the impact of oil spills.
- Address the technical needs of the communities impacted by the DWH oil spill.

EPA research will provide a greater understanding of the short- and long-term impacts on the environment and human health associated with the DWH oil spill. Research is proposed to develop innovative technologies to increase the use of green or more benign approaches to mitigate surface and subsurface oil spills and restore environments impacted by oil spills. The research strategy intends to inform not only specific decisional endpoints necessary to address the effects and impacts of oil spills, including the DWH oil spill, but also seeks to inform future scenarios involving oil spills that would potentially impact areas vital to a community's well-being. This includes all environments that are critical to a region's economy, commerce, personal livelihood, ecological sustainability, and the overall welfare of an area's inhabitants.

In order to fulfill the proposed research in the strategy, EPA will collaborate with other Federal agencies in its research, as well as leverage with States, academia, and other stakeholders. Research conducted by EPA and other collaborators will branch out in a transdisciplinary way and ultimately result in a better understanding of the impacts of the DWH oil spill on the environment and human health.

Oil Spill Research Strategy

1) Introduction

The Environmental Protection Agency's (EPA) Oil Spill Research Program has been in existence since 1990, following the Exxon Valdez oil spill and enactment of the Oil Pollution Act of 1990 (OPA-90). The OPA-90 authorizes the EPA Office of Research and Development (ORD) to conduct oil spill research. The objective of the research program is to provide environmental managers with the tools, models, and methods needed to mitigate the effects of oil spills in all ecosystems, with an emphasis on the coastal and inland environments.

The Deepwater Horizon (DWH) oil spill in the Gulf of Mexico resulted in heightened awareness by the response community, not only of the effectiveness of spill treatment methods in use today (viz., conventional booming and skimming, *in-situ* burning, bioremediation, and the application of dispersants), but also, equally important, of the ecological and human health concerns associated with spill mitigation technologies. Ecological issues concerning dispersant toxicity and dispersed oil toxicity on deep sea and surface flora and fauna, their ultimate fate in the environment, and the effects of such chemical treatment on the remediation of impacted shorelines and wetlands affected by oil are of great concern. These concerns are expressed by Congress, private citizens, and fishermen who rely on the Gulf for their livelihood. In the effort to mitigate the environmental impacts of the DWH oil spill, the government and responders applied chemical dispersants in unprecedented quantities in unfamiliar settings. In particular, deep water application of chemical dispersants was used for the first time at depths one mile below the surface. Although the efficacy of this approach has been tested, and subsurface application may have potential utility in mitigating the effects of a deep sea blowout, numerous questions remain regarding the effectiveness and environmental impact of the use of chemical dispersants as a spill mitigation tool. The DWH spill highlighted the need for innovative spill response technologies and, in addition, raised questions relative to acute and chronic health effects for spill response workers and the public.

In their January, 2011 report, the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling emphasized "the need for increased research and development to improve spill response. The technology available for cleaning up oil spills has improved only incrementally since 1990." (p. 269). [1] This strategy reflects concerns of the Commission and it will cover the potential human and environmental risks and impacts of oil spills and application of dispersants, surface washing agents, bioremediation agents, and other mitigation measures. To address many of the questions that will be considered at the highest levels of government in the years to come, this proposed strategy was developed to put forth a comprehensive research approach composed of four main themes:

- Develop a better understanding of the impacts of oil spills and dispersants application on the environment.

[1] Link to the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling Report to the President: *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling* http://www.oilspillcommission.gov/sites/default/files/documents/DEEPWATER_ReporttothePresident_FINAL.pdf

- Develop a better understanding of the shoreline, coastal, and inland environmental impacts of oil spills, including non-petroleum oils.
- Develop innovative technologies to mitigate the impact of oil spills.
- Address the technical needs of the community impacted by the DWH oil spill.

The research strategy will promote innovative approaches, such as green chemistry principles (USEPA, 2010a), in the development of less toxic dispersants and alternative remediation technologies for treating oil spills. The research strategy proposes to inform not only specific decisional endpoints necessary to address the effects and impacts of the DWH oil spill, but also to inform future scenarios involving oil spills that would potentially impact areas vital to a region's welfare. These areas include sub-tropical/temperate estuaries, wetlands, beaches, open waters, and inland water bodies that are critically important for regional economies, commerce, personal livelihoods, ecological sustainability, and the overall well-being of an area's inhabitants.

EPA research will provide greater understanding of the short- and long-term implications to the environment and public health associated with the DWH oil spill, along with support for development of innovative and more benign approaches to surface and subsurface spill remediation.

The need to direct available resources where they will be most beneficial (i.e., provide the highest return) requires a strategic focus addressing the primary decisional endpoints that EPA and other Federal agencies will meet in the future. The proposed strategy utilizes a top-down approach to guide researchers within ORD to focus their energies toward developing specific research programs and projects informing the key decisions facing Federal agencies. This approach is summarized generally and generically in Figure 1-1. The first step in this approach is the initial identification of decisions that EPA, other agencies, and stakeholders will make in the future. The next steps involve determining the key science questions and the research programs required to answer these science questions, followed by specific research design and implementation. The process delivers science products that will inform interagency prevention and response decisions. The approach does not discount bottom-up input; it simply outlines the "playing field boundaries" for relevant research.

Thus, a key starting point for this approach is to address the needs for informing a given decision. This is accomplished by identifying the primary management decisions made by EPA and other Federal agencies and their supporting science questions. The assumption is that any research strategy will be coordinated in a transdisciplinary way across agencies, as well as with organizations in the affected geographic area (e.g., the Gulf Coast Alliance and Gulf Coast Ecosystem Task Force), academia, and the private sector. The research strategy anticipates how the agencies will work together (or coordinate) to accomplish the various research themes; however, it is recognized that planning across Federal agencies, industry, and the scientific community is a dynamic process requiring flexibility on the part of EPA and its partners.

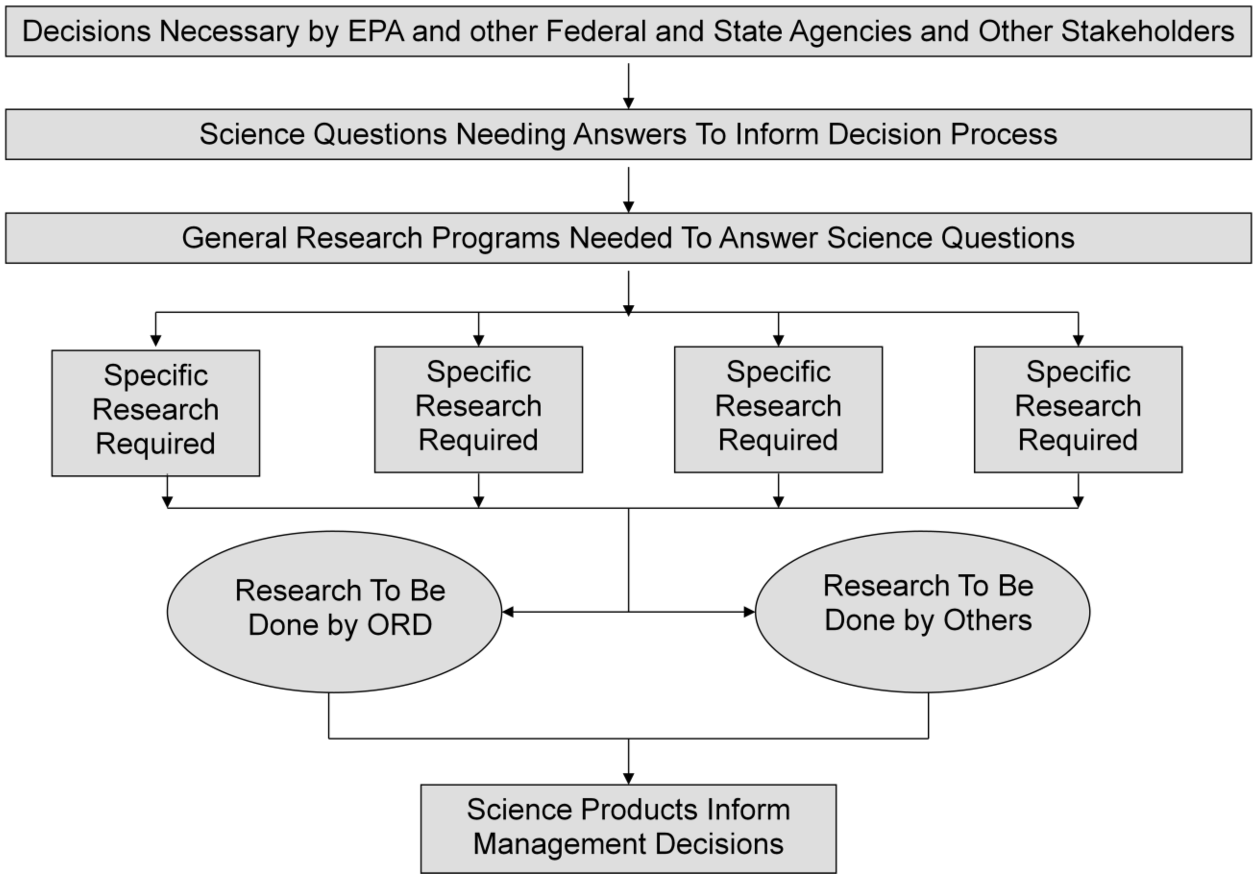

Figure 1-1. Generic Problem Formulation and Research Development Framework for the Determination of Research Priorities

a) Background on Oil Spill Research

1. The Federal Program

EPA's Administrator is chair of the recently assembled Gulf Coast Ecosystem Task Force created by the President in an effort to restore the communities and ecosystems in the Gulf of Mexico region. EPA will collaborate with other task force members to accomplish the goals of the Task Force.

Text Box 1-1 Objectives of the Gulf Coast Ecosystem Task Force

The Task Force responsibilities include:

- Coordinating the implementation of existing authorities for ecosystem restoration in the Gulf region
- Setting and coordinating restoration priorities with regulatory and river resource management activities
- Developing ways to make restoration project review and implementation more rational and efficient
- Improving coordination and communications among agencies
- Developing and fostering innovative and collaborative ways to identify, design, review, and implement restoration strategies
- Implementing project efforts based on complex, large-scale projects or on innovative approaches to resolving problems
- Identifying and resolving policy and process barriers to implementation of restoration projects
- Addressing needs raised by the DWH oil spill Natural Resource Damage Assessment (NRDA) Trustee Council
- Preparing Gulf of Mexico Regional Restoration Strategy (*Strategy*)
- Identifying ways under various authorities to address planning needs
- Improving the alignment of each agency's relevant programs and authority with the *Strategy*
- Coordinating with the Office of Management and Budget (OMB) in the development of the annual budget for the *Strategy*
- Providing oversight and accountability into Gulf of Mexico restoration efforts
- Developing performance measures and preparing a biennial report
- Ensuring development of an overarching Environmental Impact Statement

(RestoreTheGulf.gov, 2010)

The OPA-90 assigns responsibilities for oil spill preparedness, prevention, and response to a number of Federal agencies (Table 1-1). These agencies are also authorized to conduct and/or sponsor research related to oil spills. In general, the research programs in each agency are aligned with its key responsibilities.

Table 1-1 Responsibilities within the Federal Sector.[2]

Agency	Responsibility
U. S. Coast Guard	Coastal On-Scene Coordinator (OSC). Develop and enforce marine prevention regulations.
Department of Defense Army Corps of Engineers	Support OSC by providing technology, systems, and operational assistance.
Environmental Protection Agency	Inland OSC. Prepare National Contingency Plan (NCP). Manage NCP Product Schedule.[3] Develop and enforce inland prevention regulations.
Department of the Interior U.S. Fish and Wildlife Service	Resource trustee. Key participant in NRDA process in inland areas.
Department of the Interior Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE)	Develop and enforce prevention and contingency plan regulations for offshore oil and gas operations. Develop offshore response technology.
Department of Transportation Maritime Administration	Support maritime industry with guidance and technology in implementing equipment, systems, and operations to prevent spills.
Department of Defense U.S. Navy	Provide prevention and response capability to fleet and facilities. Augment national response capability through Supervisor of Salvage and Diving.
Department of Commerce National Institute of Standards and Technology	Provide support for technology development.
Department of Commerce National Oceanic and Atmospheric Administration	Scientific Support Coordinators. Resource trustee for coastal areas. Key participant in NRDA process in coastal regions.
Department of Transportation Office of Pipeline Safety	Develop regulations for pipeline spill prevention. Develop pipeline technology.

2. Historical EPA Research

EPA's Oil Spill Research Program supports the preparedness and response functions of the Oil Spill Program within the Office of Emergency Management (OEM) of the Office of Solid Waste and Emergency Response (OSWER), with resources transferred from a dedicated trust fund. For the past twenty years, EPA research has focused on three areas: (1) development of a better understanding of the fate of spilled oil; (2) development of testing protocols for spill control options; and (3) development of response agents and approaches. The research supports regulatory action under Subpart J of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which requires EPA to develop a list of substances and devices that can be used to respond to oil spills in all environments (USEPA, 2010b). EPA's research on

[2] Adapted from Oil Pollution Research and Technology Plan (Interagency Coordinating Committee on Oil Pollution Research, 1997).

[3] Subpart J of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) directs EPA to prepare a schedule of dispersants, other chemicals, and oil spill mitigating devices and substances that may be used to remove or control oil discharges (USEPA, 2010b).

efficacy testing resulted in test protocols for dispersants and bioremediation agents. Other protocols will be completed and published in 2011 and 2012 on the efficacy of surface washing agents and solidifiers.

EPA also conducts research on response options. The major focus has been on dispersion and bioremediation (USEPA, n.d.; Zhu, et al., 2001) of a variety of oils in different environmental settings, ranging from fresh water (wetlands) to marine environments (salt marshes and sandy beaches). The resulting scientific publications (U.S. National Response Team, n.d.; USEPA, 1999) are part of the foundation for guidance documents and training materials for oil spill responders. Research on response options covers not only the immediate timeframe of a spill, but also the longer-term cleanup of residual contamination.

Most research to date addresses petroleum oil, but some work has targeted animal fats and vegetable oils. Limited research has been conducted on the impact of dispersants application on oil spills. The complexity of the fate of spilled oil correlates with the properties of the oil itself and the physical, chemical, and biological properties of the spill-impacted environment. Historically, research has focused on conducting laboratory and wave tank studies to quantify the mixing energy needed for optimum oil dispersion in the water column; however, there is little research relative to the circumstances surrounding the DWH spill and the questions it raised.

Research accomplishments have included the development of practical solutions to mitigate spill impacts on freshwater and marine environments, the development and publication of remedial guidance for cleanup and restoration of oil-impacted environments, the determination of the fate routes of potential exposures, and the assessment of the resulting effects of oil contamination in the environment through effective modeling of oil transport in a variety of settings.

3. Other Federal Agencies' Research

The OPA-90 authorized the use of the Oil Spill Liability Trust Fund (OSLTF) of up to $28 million (M) annually for oil spill research across Federal agencies, subject to appropriations. OPA-90 also established the Interagency Coordinating Committee for Oil Pollution Research (ICCOPR). The ICCOPR's most recent biennial report (ICCOPR, 2009) lists the following research themes, as shown in Table 1-2, with the work EPA has conducted highlighted:

Table 1-2 Research themes supported by the ICCOPR

• Alternative technologies*
• Command, control, and communications
• Fate and behavior modeling and analysis*
• Hazardous substance response
• Natural resources injury assessment and restoration
• Oil toxicity and effects*
• Remote sensing and aerial observation
• Human dimensions
• Submerged, sunken, and heavy oils
• Shoreline assessment
• Oil-in-ice and cold weather response
• Chemical treating agents and dispersants*
• *In-situ* burning
* Research conducted by EPA

The three primary agencies that the EPA collaborates with on oil spill related research are the United States Coast Guard (USCG), the National Oceanic and Atmospheric Administration (NOAA), and the Department of the Interior's (DOI) Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE).

The USCG conducts an Oil Analysis Methodology: The Oil Identification System (OIS) (USCG, 2008) based on a multi-method approach to "fingerprinting" oils. The USCG also manages the OSLTF, which supports removal costs incurred by the USCG and EPA; State access for removal activities; payments to Federal, State, and Indian Tribe trustees to conduct NRDAs and restorations; payment of claims for uncompensated removal costs and damages; research and development; and other specific appropriations (USCG, 2010a).

In response to the DWH spill, on June 4, 2010, the USCG issued a Broad Agency Announcement (BAA) to establish an Interagency Alternative Technology Assessment Program (IATAP). The IATAP was aimed at developing a well defined, documented, systematic, and fair government-managed process to solicit, screen, and evaluate vendor/other government agencies/academia-suggested technologies in support of ongoing response activities (USCG, 2010b).

NOAA conducts research to improve the basic understanding of coastal and marine spills and advances capacity for:

- Responding to spills in a manner that minimizes the impacts to biological, economic, social, and cultural resources;
- Assessing the impacts of the spill and the response efforts on resources;
- Restoring impacted resources with the highest degree of efficiency and effectiveness;

- Utilizing alternative response technologies (e.g., *in situ* burning or the use of dispersants);
- Advancing assessment capabilities by developing a robust database for managing shoreline assessment information for large and complex spills.

The Coastal Response Research Center (CRRC) was established as a partnership between NOAA's Office of Response and Restoration and the University of New Hampshire in 2004. Currently, 50 percent of CRRC-funded projects examine the issues of measuring and predicting the effects of oil and dispersed oil components on ecological endpoints. NOAA also leads studies on the NRDA process in coastal zones (NOAA, 2008). DOI generally is the lease federal trustee for inland spills.

NOAA's research includes the Dispersant Mission Planner 2 (DMP2) tool, which spill responders and planners can use to assess dispersant application system performance. NOAA, in conjunction with EPA and USCG, has also developed Special Monitoring of Applied Response Technologies (SMART), which is a cooperatively designed monitoring program for *in-situ* burning and dispersants. SMART relies on small, highly mobile teams that collect real-time data using portable, rugged, and easy-to-use instruments during dispersant and *in-situ* burning operations. The SMART program is a joint project of the following agencies: USCG, NOAA, EPA, BOEMRE, and the Centers for Disease Control and Prevention (CDC) (NOAA, 2009).

Within the DOI, for more than 25 years, BOEMRE has maintained a comprehensive, long-term research program to improve oil spill response technologies. BOEMRE has funded more than 120 projects directly related to oil spill research. These projects cover topics ranging from oil behavior in water to chemical treating agents, remote sensing, spill response in arctic environments, mechanical containment options, and *in-situ* burning. BOEMRE has contracted with various organizations to conduct numerous studies on dispersants including:

- Efficacy (e.g., oil types, cold water, and long-term effectiveness)
- Effects
- Dispersant removal techniques
- Oil-to-dispersant ratio
- Application (e.g., window of opportunity and dilute versus neat) (DOI, 2010a)

Appendix A (Table A-1) summarizes ongoing and anticipated oil spill research conducted by Federal agencies. Table A-1 lists the organization conducting the research, the research objective, and research area. It is expected that several of the specific research areas will result in collaborative research with other Federal and State agencies, academia, and the private sector.

4. Non-Federal Research

Numerous State agencies, academic institutions, and the private sector are also conducting oil spill research or plan to undertake oil spill research in the near future. Table B-1 in Appendix B lists these oil spill related research activities conducted by academic institutions on the DWH oil spill, including detailed information on the organization conducting the research, the research objective, and the research area.

b) Research Overview

The DWH spill in the Gulf of Mexico highlights the need to broaden and refine oil research programs throughout the Federal government. EPA is responding in two ways: first, by taking on short-term studies that can be of immediate use; and second, by developing the oil spill research strategy with a more holistic approach to effects and effectiveness of oil spill response options. Projects already initiated to respond to the DWH spill include: (1) testing the toxicity of eight commercial dispersants listed on the NCP Product Schedule; (2) measuring and quantifying the dispersion effectiveness of eight commercial dispersants on the NCP Product Schedule; (3) quantifying the biodegradability of South Louisiana crude oil, dispersed oil, and two dispersants, one of which was used in the DWH spill, at two different temperatures; (4) measuring air emissions from *in-situ* ocean burning during the DWH spill; and (5) evaluating alternative response technologies that are ready for deployment.

EPA is leveraging its research and development efforts by collaborating with other Federal agencies such as NOAA, DOI, USCG, National Institute of Environmental Health Sciences (NIEHS), and others. These Federal agencies are conducting their own research on the potential impacts of oil spills on the environment and human health. EPA is collaborating with the Occupational Safety and Health Administration (OSHA) on reviewing data on exposure measurements to evaluate the impact of the oil spill on the safety of DWH oil spill workers. In addition, USCG, NOAA, and BP are involved in this work. EPA is also coordinating with NOAA and U.S. Geological Survey (USGS) on the Ecosystem Restoration Task Force, led by EPA's Administrator. Figure 1-2 illustrates the primary research areas conducted by various Federal agencies that will inform EPA's oil spill research and development.

Dispersants	
EPA	Toxicity Fate & transport
FDA and NOAA	Bioaccumulation
ATSDR	Human health impacts
NIOSH	Toxicity research

Ecosystem Effects & Restoration	
NOAA*	NRDA
USGS*	NRDA
EPA*	Improved methods research Supports NRDA Assessing changes in human well-being Long-term ecosystem impacts
USFWS	Acute death of animals
Gulf of Mexico Alliance	Long-term impacts on Gulf region

* Members of Ecosystem Restoration Task Force

Innovative Technology Development	
DOI BOEMRE	Offshore response technology
EPA	Develop response technology and support regulations
NOAA	Support technology development
NIST	Support technology development
Gulf of Mexico Alliance	Technology development for offshore oil spills

Human Health	
NIEHS and NIEHS-NTP	GuLF worker cohort study Toxicity studies
OSHA	Worker safety
FDA and NOAA	Food source contamination
ATSDR	Human exposure impacts
EPA	Risk assessment/ communication to communities Support NIEHS-NTP
NIOSH	Toxicology studies

Figure 1-2 Federal Research Areas

1. Purpose

EPA research will provide a greater understanding of the short- and long-term implications to the environment and public heath associated with not only the DWH oil spill but all spills in general, including those in the inland zone where EPA has primary delegated authority for management responsibility. With the advent of the Energy Independence and Security Act of 2007, EPA's role in inland oil spill management will grow as the Nation tries to wrest itself from dependence on foreign oil by the production, transportation, and use of biodiesel and biofuels. As these alternative fuels increase in volume, the number of accidents is expected to rise, and EPA must be ready to respond to such spills. The research will also support development of innovative and more benign (greener) approaches to spill remediation. Specifically, the strategy proposes a research approach focusing on four main themes to:

- Develop a better understanding of the impacts of oil spills and dispersants application on the environment.
- Develop a better understanding of the shoreline, coastal, and inland environmental impacts of oil spills, including non-petroleum oils.

- Develop innovative technologies to mitigate the impact of oil spills.
- Address the technical needs of the community impacted by the DWH oil spill.

2. EPA Role and Research Prioritization

EPA's Oil Spill Research Program is an applied program based on high quality, sound science that promises to provide answers to real and important emergency spill response and environmental protection challenges. Its research informs EPA's regulatory decision-making and policy development for oil spill prevention, preparedness, and response programs.

Research will focus broadly to improve understanding of the environmental impacts and effectiveness of dispersants and chemically dispersed oil. The work will address environmental fate, transport, exposure, and effects of released crude oil, and the application of dispersants as a mitigation tool. Research on coastal and inland impacts from oil spills will address effects on these ecosystems and explore innovative ecological restoration methods. Research undertaken will support the design of innovative and more benign approaches to address oil spill mitigation and remediation in the future. A particular focus on the application of green chemistry principles (USEPA, 2010a) will provide effective and sustainable products while reducing their toxicity and persistence in the environment. EPA will also address human health issues in an active collaboration with a large, cross-Federal agency activity.

With the research strategy, EPA will continue to provide its historical expertise in impact assessment and technology innovation. Higher priority research will be directed to address critical science questions associated with the DWH spill, including dispersants research topics, development of alternative technologies in spill response, and remediation of coastal ecosystems. Within each of the four main research themes, the progression of research topics within the theme is presented. Progress will depend on the level of effort available to apply to the research strategy.

To address significant knowledge gaps, the EPA research grants program has identified priorities in three technical areas: (1) development of mitigation technologies; (2) development of effective chemical dispersants; and (3) understanding ecosystem impacts. In addition, the grants program will support a community outreach effort, which will empower Gulf Coast communities with an independent understanding of the underlying technical issues related to oil spill contamination and mitigation of impacted sites and encourage these communities to more fully participate in solving their environmental problems. Grants will be awarded in 2011.

3. Science Integration

Science integration is planned on three levels. First, within EPA's portfolio, proposed projects will be reviewed for cross-theme implications. Second, ongoing ICCOPR communications, especially the prospective section of the biennial report, will be used to integrate projects across agencies. Finally, EPA will continue communication with EPA's emergency responders (e.g., OSCs and Special Teams), EPA's Response Support Corps, States, and other stakeholders to ensure that EPA's research and products meet their needs.

Gulf Coast Ecosystem Task Force

EPA's Administrator chairs the Ecosystem Task Force, established by the President in response to the DWH oil spill. EPA will collaborate with other Task Force members, including other Federal, State, and Tribal government representatives, to achieve the objectives of the Ecosystem Task Force. Specifically, the Ecosystem Task Force will work with existing advisory committees to reinforce the use of relevant scientific and technical knowledge in restoration planning and decision-making to coordinate with NRDA restoration activities.

BP and Gulf of Mexico Alliance Research Initiative

In response to the DWH oil spill, BP dedicated $500M in funds to the Gulf of Mexico Research Initiative (GRI) to study the effects of the oil spill and the potential impact on the environment and public health. On September 29, 2010, BP and the Gulf of Mexico Alliance announced the implementation of the ten-year GRI program, which will be administered by the Gulf of Mexico Alliance. BP and the Gulf of Mexico Alliance will appoint a board of scientists from academic institutions to manage the GRI. Prior to the implementation of the program, fast-track grants were made for the following: Louisiana State University ($5M), the Northern Gulf Institute ($10M), the Florida Institute of Oceanography ($10M), the Alabama Marine Environmental Sciences Consortium ($5M), and the NIEHS ($10M). The research goals include:

- Identifying the fate and transport of contaminants associated with the DWH oil spill;
- Determining the chemical evolution and biodegradation of the contaminants;
- Analyzing environmental effects of contaminants on ecosystems in the Gulf region and the science of ecosystem recovery;
- Developing technologies to improve detection and characterize, mitigate, and remediate offshore oil spills; and
- Integrating the preceding objectives to address the effects on public health (BP, 2010).

4. Collaboration and Leveraging

Historically, within EPA, ORD has had a modest program of approximately $1M per year for oil spill research. ORD contributed to EPA's response to the DWH spill by addressing short-term science issues, and the research strategy herein reflects an expanded program that will leverage existing research expertise and improved collaboration with EPA Program Offices, Federal agencies, States, foreign governments, and the scientific community. Specific collaboration opportunities are discussed under each research theme.

Since the DWH oil spill, EPA has established scientific collaboration activities with participating Federal agencies, States, and other organizations. These include:

- NSF on a series of short-term grants to address a variety of immediate science issues associated with the DWH spill;
- Department of Health and Human Services (DHHS) (NIEHS, National Institute for Occupational Safety and Health [NIOSH], and CDC's Agency for Toxic Substances and Disease Registry [ATSDR]) on human health research discussions;
- NOAA on dispersant use, fate and transport, oceanographic and trajectory monitoring, and effects;
- USCG on alternative technologies and risk management measures;
- National Park Service (NPS) on ecological restoration and ecosystem services/well-being;
- Woods Hole Oceanographic Institution, the largest private ocean science institution in the world, on monitoring dispersed oil at depths in the Gulf of Mexico;
- EPA Regions 4 and 6 and the States of Louisiana, Mississippi, Alabama, and Florida on spill mitigation and cleanup of wetlands and marshes, and EPA Region 5 on analytical chemistry techniques; and
- General research collaboration through the ICCOPR. Significant opportunities exist to collaborate with many of those agencies as a means of leveraging EPA's resources to achieve the most efficient answer to critical questions. Collaboration is also planned with DFO-Canada to conduct important and timely wave tank research on dispersants.

2) Dispersants

Conventionally, oil dispersants are used to disperse oil slicks floating on the water surface into the water column by breaking down the oil slick into tiny droplets that are driven by wave energy into the subsurface. Through this process, dispersants generally shift the toxicity of the oil from waterfowl to fish and macroinvertebrates living in the water. Dispersants reduce the amount of oil reaching the shore and support more rapid metabolism of the oil by aquatic oil-degrading microorganisms. Without the use of dispersants, oil that contaminates the shore can disrupt and threaten subtidal and intertidal species, impact sensitive coastal areas and coral, and cause other attendant ecotoxicological problems. When dispersants are used in deep sea blowouts such as the DWH spill, managers try to use a sufficient amount of dispersants to closely match the effective dispersant-to-oil ratio, thereby saving chemicals and hopefully mitigating the ecotoxicological effects on the deep sea ecology. This assumes the oil flow rate can be adequately and quickly calculated.

Several studies have assessed the toxicity of dispersant application on aquatic environments. Two National Research Council (NRC) reports (1989 and 2005) discuss numerous issues associated with the use of dispersants, and a review article by Exxon-Mobil scientists assesses the toxicity of the primary dispersants, Corexit® 9500 and 9527, used by BP in the Gulf of Mexico in 2010(George-Ares and Clark, 2000). Their analysis was based on more than 20 papers from the open literature and another 10 unpublished reports. Many papers written in the open literature evaluate dispersant use, most of which involve assessing the acute toxicity (LC_{50}) of dispersants in aquatic organisms; some evaluate the effect of dispersants on the degradation of oil. Beyond dispersants, Walker, et al., (1999) review chemical agents dealing with oil spills that do not involve dispersants, such as herding agents, demulsifiers, solidifiers, elasticity modifiers, and shoreline-cleaning agents.

a) Problem Formulation

As part of the efforts to mitigate the impact of the DWH oil spill, chemical dispersants were deployed for the first time at depths one mile below the water surface in amounts not experienced before. Although the effectiveness of this approach has been tested, and subsurface application may have potential utility in dispersing the oil, the questions raised concerning the efficacy and environmental impact of using chemical dispersants in general and specifically in a deep sea environment need to be addressed.

The proposed dispersants research will focus broadly to better understand the environmental impacts of dispersants and chemically dispersed oil. This section presents primary management decisions, key science questions, and anticipated outcomes for four research areas: (1) efficacy, (2) fate, transport, and bioaccumulation; (3) adverse ecological effects; and (4) sustainable green chemistry alternatives for producing less toxic dispersants. Figure 2-1 presents the process that will focus the research to inform decision-making. It is anticipated that EPA will be the primary research organization engaged in developing green dispersants, although EPA welcomes and encourages leveraging with other Federal agencies in this regard.

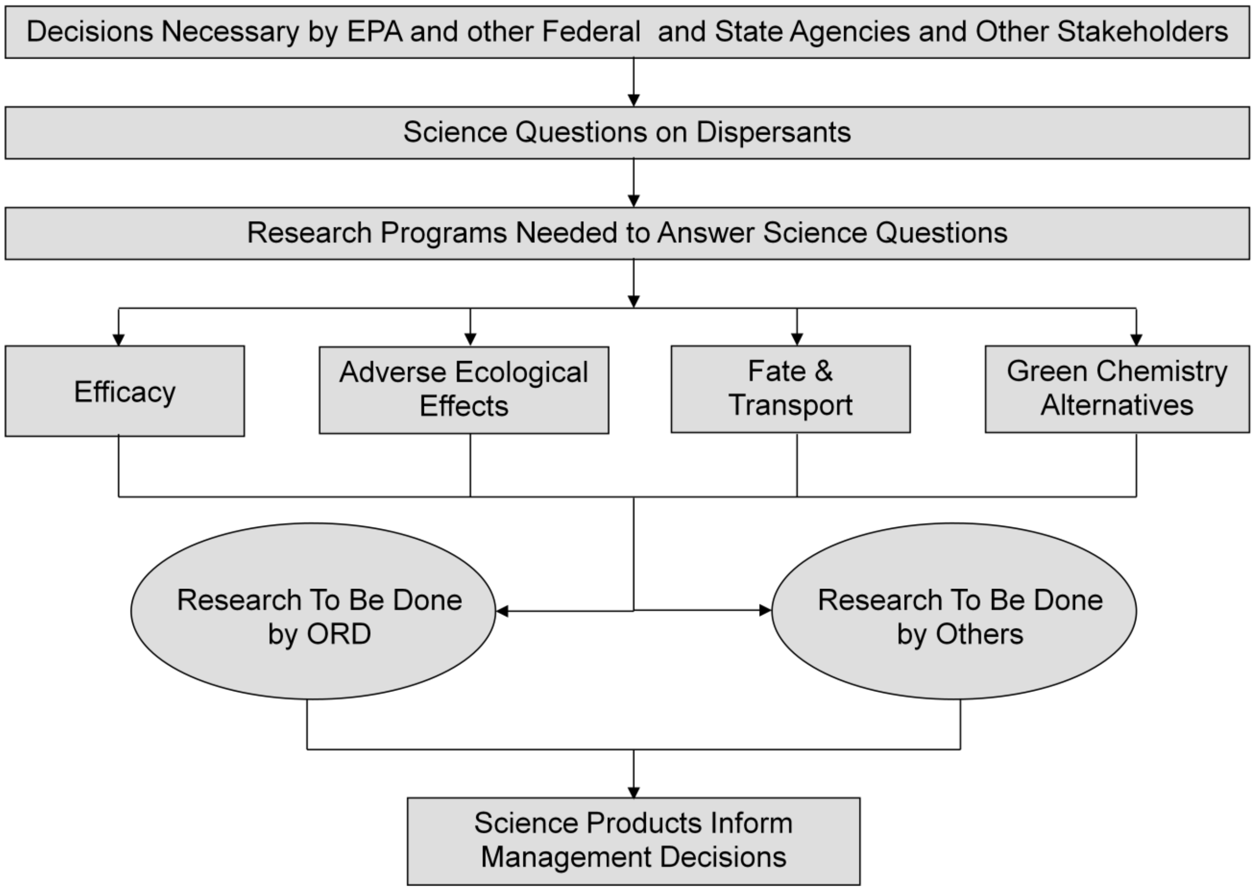

Figure 2-1 Dispersants Problem Formulation and Research Development Framework

b) Related Federal Research Activities

The research proposed and currently under way regarding dispersants will be accomplished through cooperation among several Federal agencies, including the U.S. Food and Drug Administration (FDA) and NOAA, NIOSH, and ASTDR. The projects developed to address issues resulting from the DWH spill are briefly described below.

FDA and NOAA are collaborating on research concerning the bioaccumulation of dispersants in Gulf seafood. Initially, sensory tests were conducted to determine the safety of seafood for consumption; however, a new test has been introduced. The new test detects dioctyl sodium sulfosuccinate (DOSS), which is a major component of the dispersants used in the Gulf. The new test, coupled with previous research on how certain species metabolize DOSS, has provided scientists with information for exposure experiments (NOAA, 2010a).

NIOSH is performing basic toxicology studies on crude oil and dispersants received from BP. The focus is on two routes of exposure: inhalation and dermal. NIOSH has health hazard evaluation studies in progress and has rostered 51,000 workers. Another potential cohort of workers is composed of those on rigs that were close to DWH and maintained operation for several weeks after the spill.

ASTDR evaluated environmental data collected by other Federal agencies. ASTDR assessed the data to determine the potential environmental impact and human health implications. ASTDR evaluated the relationship between characteristics of the oil and the distance from the wellhead, finding evidence of a clear pattern of weathering; however, to date no evidence of potential human health concerns has been found.

c) Proposed Research Activities

Short-term research has focused on assessing the environmental and human health hazards of the spilled oil, including physically or chemically dispersed oil, as well as the effectiveness and consequences of remediation approaches. Additional studies are intended to more fully characterize the potential toxicity and persistence of dispersants and to help inform decision-making regarding appropriate conditions for dispersant use.

1. Efficacy

Decision Context (What question is the decision-maker asking?)	Key Science Questions (What research will answer that question?)	Anticipated Outcomes (How will this research inform the overall decision?)
Which dispersants are the most efficacious for particular situations?	When is the use of dispersants most effective and what are the key parameters under which spilled oil is dispersible, such as temperature, mixing energy?	Inform Subpart J regulatory actions. Inform selection of the most effective dispersant on a spill-by-spill basis.
What regulatory actions under Subpart J are needed for dispersants?	What alternative dispersants are available? How effective are they? How toxic are they?	Inform Subpart J regulatory actions.

When the Baffled Flask Test (BFT) is published, through the *Federal Register* for final adoption by EPA, the test will be the official protocol to be used for listing future dispersant products on the NCP Product Schedule. The previous test was shown to be inadequate by EPA published research in the early 2000s, which prompted the development of the current BFT. This research area will evaluate different types of oils, temperatures, salinities, and mixing and settling times to determine how robust the BFT method is under various conditions.

Research to assess the efficacy of dispersants

Studies will evaluate the efficacy of the dispersants so that the OEM can make more informed decisions regarding the potential benefits and liabilities of dispersant use. Such research should be conducted under a variety of conditions (e.g., water temperature, salinity, wave energy, mixing times, quiescent times) to simulate the broad range of conditions under which real-world response scenarios will play out and so that the information generated from the work can aid in development of methods for evaluation of products submitted to the NCP Product Schedule that are appropriate for decision-making. Further validation of methods will be performed by developing field tests for evaluating the effectiveness of dispersants. Methods will be applicable to both water-soluble and oil-soluble dispersants and should consider different salinities, water depths, seawater temperatures, application methods, and other variable parameters.[4] Comparisons of the use of dispersants with other methods, including mechanical removal techniques (sorbents, booming, skimming, etc.), *in-situ* burning, and bioremediation will be conducted. Generally recommended application rates will be developed for use in immediate responses. Techniques will also be developed for site-specific rates to be applied once more site-specific information is known about a given spill.

Research to identify the behavior of deep sea dispersed oil plumes

The optimal composition and factors involved in enhancing the dispersion of oils of all types will be evaluated and defined. These factors include temperature, mixing energy, type of oil (weight, viscosity, pour point, percentage of asphaltenes, polar compounds, and toxic components such as polycyclic aromatic hydrocarbons [PAHs], etc.), salinity, and sub-sea conditions (dissolved oxygen; hydrostatic pressure; water solubility and composition of dispersants and their constituents; species at risk; toxicity to water column species at the surface, within the water column above and below the pycnocline, and at extreme depths). Droplet size also will be investigated, given that the smaller the dispersed oil droplets are, the less they will re-coalesce, and it is still uncertain exactly how large droplets must be for re-coalescence to take place. Such research will also address energy condition (e.g., alternating high-energy and quiescent conditions) effects on re-coalescence.

Research to evaluate the effectiveness of oil dispersion in the field

Increasing the quantitative knowledge of vertical and horizontal diffusivities and advection of dispersed oil in water will provide a better understanding of dispersed oil behavior in seawater below and above the pycnocline and inform the relative effectiveness of dispersants at surface and subsurface conditions. It is known that vertical diffusivity transports droplets deeper into the water column, whereas buoyancy causes them to return to the surface. Diffusivity also decreases under the influence of vertical density stratification. Wave energy decreases exponentially with water depth. Advection from mixing of oxygen-rich waters with oxygen deficit waters is likely to be significantly higher than diffusion effects. Additional research is needed to better understand the behavior of dispersed oil under these varying conditions. Leveraging such work with NOAA resources would be invaluable and is required to accomplish this aspect of the strategy.

[4] Collaboration with DFO-Canada is under way for dispersant testing in Arctic waters in FY 2011. This research will establish the requisite information to guide use of dispersants in the Arctic.

2. Fate, Transport, and Bioaccumulation

Decision Context	Key Science Question	Anticipated Outcomes
Do dispersants bioaccumulate in aquatic organisms?	What data are available on dispersant bioaccumulation? Are more studies needed on dispersant bioaccumulation?	Research will provide information about whether dispersants can bioaccumulate through a food chain.
How long do dispersed oil and dispersants from surface, subsurface, and deepwater applications remain in the environment?	What is the environmental fate and transport of dispersed oil and dispersants from surface, subsurface, and deep water scenarios?	Research will provide information on the environmental persistence of dispersants and dispersed oil, which will inform an evaluation of long-term human health and ecological impacts.
What happens to dispersants and dispersed oil when used on deep sea applications?	What are the key variables needed to better understand the coalescence and resurfacing of dispersed oil droplets to develop models for tracking the movement of dispersed oil plumes at the surface, subsurface, and in the deep sea?	Research will provide information to decision-makers on how much oil is dispersed chemically versus physically. If extreme turbulence is all that is needed, then chemical dispersants may not be required.
What methods are available to track dispersed oil in the deep sea?	How can EPA collaborate to improve the SMART protocol for monitoring dispersed oil in the environment, especially the use of innovative and advanced fluorometric techniques?	Improved methods will allow managers to better track dispersed oil plumes and inform remediation decisions.

Research to evaluate the bioaccumulation of dispersants on aquatic organisms

Research will evaluate the issue of bioaccumulation of dispersant chemicals in the food chain. Environmental chemistry estimation methods will be used as a first step to predict the bioaccumulation potential of individual compounds used in dispersants. Any individual dispersant chemicals predicted to possibly bioaccumulate will be evaluated in laboratory studies. Dispersant mixtures will be studied to evaluate whether mixture interactions promote bioaccumulation of the chemicals. Additional research will be conducted in collaboration with NOAA and FDA.

Research to determine the fate and transport of dispersants

Environmental fate estimates are available for some of the individual chemical components of the primary dispersants used in the DWH oil spill. However, little is known about the fate and transport of dispersants *per se*, dispersed oil, and oil *per se* as applied in the deep sea. Research will produce data on environmental half-lives of these chemicals in the environment. Data will support current models to refine estimates of the fate and transport of these materials. For example, four-dimensional (4-D) mapping of the movement of dispersed and non-dispersed oil plumes in the water column will be developed, which could be leveraged with NOAA's sonar and underwater trajectory modeling. In addition, utilization of data from effectiveness tests (lab and wave tank), in collaboration with Canadian scientists, will support the development or improvement of models involving oil with and without dispersants.

A key factor in providing guidance on spill response technologies is developing a firm understanding of the science behind spill behavior in the environment. The development and application of analytical tools can facilitate our understanding of these processes.

Analytical methods will continue to be developed to assess the fate and transport of dispersants, dispersed oil, and oil alone in the field. A variety of dispersants will be analyzed to identify chemical markers to allow detection and tracking through the environment. In parallel, research will determine the use of such markers to detect dispersants in a variety of complex environmental media, including sea water, weathered oil, tar balls, and mousse.

Analytical methods and tools will be developed and applied to allow for a more complete understanding of the chemical nature of the currently approved, and used, dispersants, as well as applied to new dispersants as they are developed using green technologies. These same analytical tools can also be applied to understanding the environmental sinks of dispersants, whether in the water column, oil mousses, tarballs, sediments, aquatic organisms, etc. Analytical tools will be developed and applied to track and assess the fate of dispersants and oils into the shoreline and coastal environments, and their final disposition in the environment (e.g., sediments, coastal estuaries, aquatic plants, fish). Finally, analytical tools will be developed and applied to assist in the study of the toxicology of dispersants and oils in the environment. Support can be provided in the form of quality assurance, using analytical chemistry tools, for both the toxicity testing and the seawater/oil/dispersant mixture toxicology research efforts.

Other studies will evaluate the biodegradation of dispersants and dispersed oil to assess how long the substances persist in the environment. Studies proposed include a comparison between the long-term degradation of oil that is and is not chemically dispersed. These tests will be performed using a range of conditions to determine the effects that different variables, such as temperature, salinity, and pressure, have on the degradation processes. With this information, EPA may be able to better evaluate which specific dispersant might be appropriate in varying environmental conditions and relevant to a variety of oil spill and dispersant application scenarios (multiple oils, dispersants, and laboratory and wave tank research), thus better informing future decision needs.

Research to evaluate the impact of deep sea injection of dispersants

Deep sea injection of dispersants into blowout releases is the least understood treatment approach. Additional research will improve the understanding of the impact of turbulence on the creation and persistence of small oil droplets. It is essential to determine whether these droplets stay dispersed and neutrally buoyant, or if the use of chemical dispersants helps prevent the recoalescence of the droplets permanently. This is critical because currently it is still not fully understood whether the use of chemical dispersants in the DWH spill was useful.

Research to identify dispersant tracking methods

An issue requiring further investigation is the use of fluorometric techniques throughout the water column that are more specific to hydrocarbons as opposed to the use of insensitive chromophoric dissolved organic matter (CDOM) sensors. CDOM sensors use excitation and emission wavelengths not specific to fluorescence of hydrocarbons *per se* in the water. Instruments already exist that may address this need (e.g., Chelsea Aquatrack *in-situ* fluorometer), but few data exist to demonstrate their comparative effectiveness. This type of research will supplement the SMART Tier 3 protocol now in use to track dispersed oil in the sea. In addition, little information has been developed in the DWH spill to understand the extent to which methane has affected the environment and the amount of total inorganic carbon (TIC) (i.e., dissolved carbon dioxide [CO_2]) that has been generated due to hydrocarbon biodegradation at depth. This type of monitoring will greatly aid in determining the fate of the oil, dispersed oil in the water, and help mitigate the confounding effect methane flow plays on estimating the total oil discharging in the deep sea. Therefore, other deep sea instruments such as the CONTROS and/or METS will be evaluated for their utility in monitoring methane and CO_2 concentrations at depth.

3. Adverse Ecological Effects

Decision Context	Key Science Questions	Anticipated Outcomes
Are oil dispersant products or chemically dispersed oil chronically toxic to aquatic flora and fauna?	What are the ecotoxicological effects of oil dispersant products and chemically dispersed oil?	Research will be used in ecological risk assessments to inform management decisions on the best products for dispersing oil into the water column.
Will oil dispersant products be toxic to aquatic species when injected at the surface or underwater to mitigate spill impacts from deep sea blowouts?	What are the ecotoxicological effects of dispersants in surface and deep sea injection exposures?	Research will be used in ecological risk assessments to inform management decisions for deploying the least toxic dispersants for mitigating oil spills.
Will the effective use of dispersants reduce the impacts of the spill to shoreline and water surface resources ***without*** significantly increasing impacts to water-column and benthic resources? (NRC, 2005)	What are the comparative ecotoxicological effects of dispersants in surface and deep sea injection exposures versus shoreline?	The dispersant ecological risks will be compared to coastal ecological risks from oil spills in a variety of scenarios. This comparative assessment will address key questions on dispersant use.

In the initial days of the DWH spill response, EPA conducted chemical analyses to characterize the source oil and the applied dispersants in an effort to identify the chemical composition of those substances. The potential ecotoxicological impacts of the oil and dispersants were estimated based on published and modeled values for each chemical component. EPA used relevant information on volatility, biodegradation, persistence, toxicity, carcinogenicity, solubility, and other factors to inform decisions on the use and efficacy of dispersants listed on the NCP Product Schedule. Additional research will evaluate the components of those substances and generate empirical evidence to verify modeled values.

Dispersant formulations currently in use are much less toxic than dispersants manufactured prior to 1970 (NRC, 2005). Generally, the acute toxicity of the current generation of dispersants to fish and aquatic invertebrates is classified as slightly toxic to practically nontoxic, with LC_{50}s ranging from 12 to 500 ppm (NRC, 2005; Hemmer et al., 2010). Typically, larval stages of aquatic organisms are more sensitive to contaminants, whereas the sensitivity of embryos can vary based on species-dependent differences in egg permeability. However, few studies with dispersants and dispersed oil have been conducted with multiple life stages of the same species under identical exposure regimes. Conflicting results have been reported for life stage sensitivities to dispersants and dispersed oil with some studies suggesting that embryo-larval stages are more sensitive than adults (Wilson, 1977; Clark et al., 2001), whereas other studies indicate little difference in toxicity between life stages (Coutou et al., 2007). Specific constituents such as PAHs and monoaromatics appear to contribute to the increased toxicity (i.e., lower LC_{50}s) observed for early life stages of fish exposed to oils and dispersed-oils (Coulliard et al., 2005, NRC, 2005). Additional toxicity testing of dispersants and dispersed oil will address a broad range of endpoints in a variety of aquatic species (microbial, plant, and animal) that cover a range of trophic levels.

Research to determine the toxicity of dispersants in all environments

Research will address chronic toxicity testing of dispersants both to assess sublethal effects on sensitive organisms and to address public concerns about chronic effects of dispersants on aquatic organisms. In addition, more studies should be designed to quantify the toxicity of dispersed oil on various water column fish and invertebrates at mesophilic and psychrophilic temperatures in a more environmentally relevant setting. Recent EPA tests (USEPA, 2010c) have determined the acute toxicity of eight dispersants to two Gulf of Mexico species, and the literature also reports data on acute toxicity for a limited number of species and dispersant products. Virtually no data have been published on the chronic toxicity of dispersants, due to previous assumptions about both limited environmental applications and persistence. However, the DWH spill proves that longer-term exposures of dispersants and dispersed oil are possible and must be reckoned with. The research would provide data critical to assessing the uncertainties associated with longer-term hazards of sublethal dispersant and dispersed oil exposure on sensitive organisms.

Although most traditional aquatic toxicity studies evaluate only lethality (LC_{50}), additional endpoints will be included involving genotoxicity, neurotoxicity, developmental and reproductive toxicity, receptor binding, and *in vivo* endocrine effects of dispersants using small fish omic models. Critically important is a systematic assessment of dispersants, oil, and dispersed oil across life stages of a wide variety of aquatic species. These projects will develop chronic ecotoxicity benchmarks for assessing the longer-term impacts of oil dispersants. Additionally, all toxicity studies of dispersants to date involve only surface applications. Future research will examine the aquatic toxicity resulting from the release of dispersants at the surface versus release in the water column.

Research to determine the toxicity of dispersants in deep sea and surface applications

Regarding the ecotoxicity of dispersed oil in the deep sea and shallower environments, research efforts have quantified the toxicity of dispersed oil and dispersants alone in standard toxicity tests (i.e., *Mysidopsis bahia* and *Menidia beryllina*) using water accommodated fractions (WAF) and chemically enhanced WAF (CEWAF) of the oil. The question remains, however, as to whether use of WAF and CEWAF for toxicity exposures is indicative of real world exposures to dispersed oil. Research will be conducted to address this question by coupling toxicity exposures to dispersed oil prepared using the BFT.

EPA laboratories will conduct research to determine the best approach to list dispersant products on the Schedule. In addition, research using more wave tank studies will be designed to quantify the toxicity of dispersed oil on various water column fish and invertebrates at mesophilic and psychrophilic temperatures in a more environmentally relevant setting. Resource leveraging with the Canadian government using the co-owned EPA/DFO wave tank will be necessary to get the most cost-effective results from the research.

Research to compare the ecotoxicological effects of dispersants in surface and deep sea injection exposures versus shoreline

Comparative risk assessments will be conducted to inform risk-management options. Comparative assessments of the toxicity of dispersants on aquatic organisms versus the impact to coastal biota will be performed. Risk characterization will estimate the impacts to coastal systems versus effects to organisms in the water column and benthic biota in several exposure scenarios. These assessments will provide decision makers with more complete descriptions of ecological risks.

4. Green Chemistry

Decision Context	Key Science Questions	Anticipated Outcomes
What green chemistry methods are available to use as effective dispersants?	What dispersants can be produced that have a "lighter" environmental footprint than petroleum-based products?	Dispersants will be proposed that have reduced life cycle assessment (LCA) ecological impacts to make available "green" options to decision-makers.

Research to identify effective "green" methods of oil dispersion

Research also incorporates the evaluation of more benign (green) approaches to dispersants when mitigating the effects of oil spills. Preferred methods will provide effective processes and products while reducing their toxicity and persistence in the environment. The research will inform decision-makers in choosing dispersant products. The research will require collaboration with several laboratories in ORD. Discussions are currently under way on how to address the development of green dispersants for use in oil spill mitigation.

d) Progression of Dispersant Research

EPA recognizes the need to increase research on the potential risks to human health and the environment resulting from oil spills. The research strategy illustrates the problem formulation developed for dispersants that identifies the specific science questions and subsequent research activities that will ultimately inform management decisions. The research on dispersants includes evaluation of the environmental fate and transport estimates for individual chemicals and chemical mixtures of the primary dispersants used in oil spills, characterization of the adverse ecological effects associated with oil spills including toxicity of dispersed oil products and chemically dispersed oil, evaluation of the efficacy of dispersants, and assessment of green alternative approaches to dispersants when mitigating oil spills. Figure 2-2 illustrates the progression of proposed dispersant research from Fiscal Year (FY) 2011 through FY 2015.

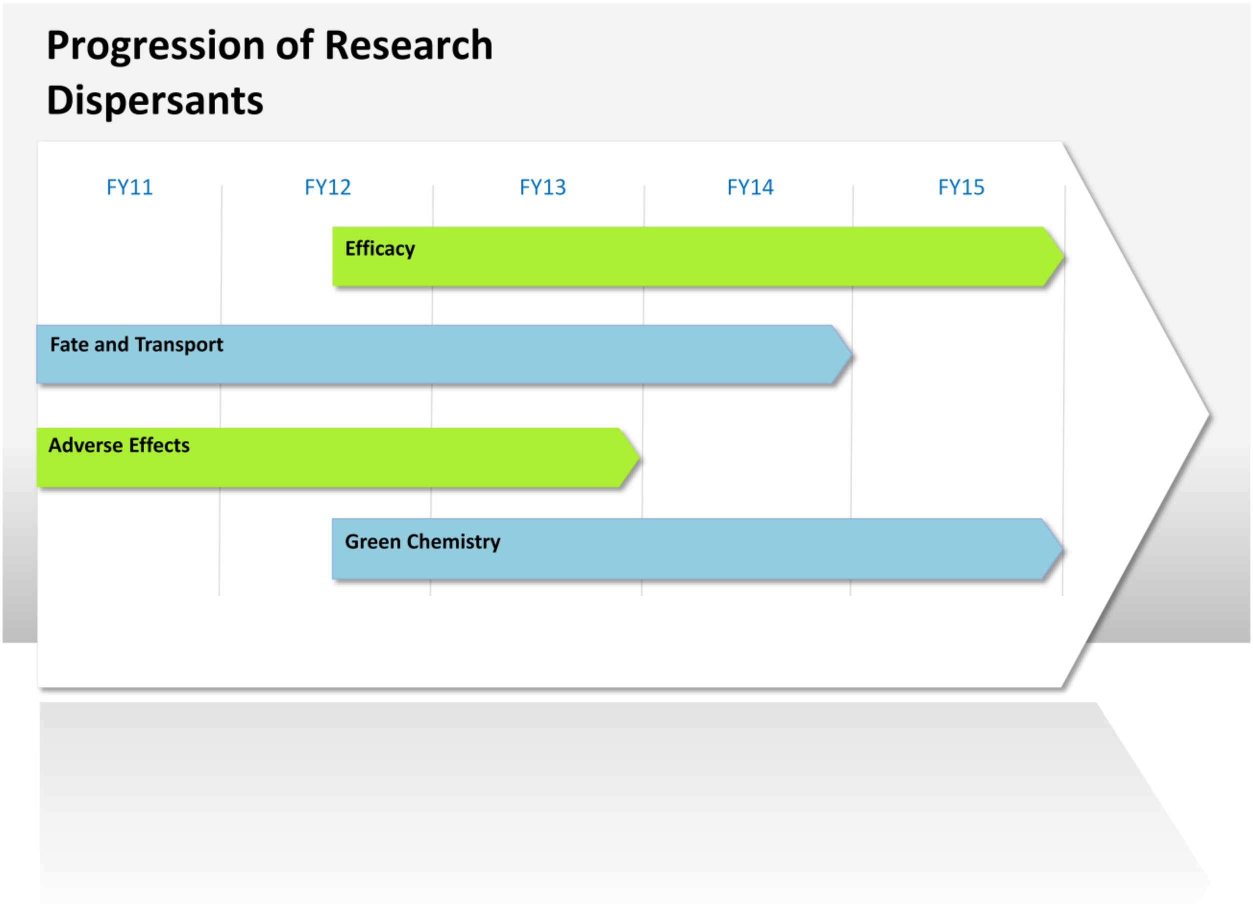

Figure 2-2 Progression of Dispersants Research

3) Shoreline, Coastal, and Inland Effects Research to Inform Oil Spill Decision-Making

a) Problem Formulation

In the weeks and months following the DWH explosion and ensuing oil spill, Federal agencies found that some key scientific information was unavailable to inform critical decision-making concerning the emergency response and for anticipated decision-making regarding remediation once the spill was contained. Many of the scientific questions involved the movement of surface and sub-surface oil plumes, the ultimate deposition of the released oil and oil-dispersant mixtures, and the anticipated effects of remedial actions taken to forestall the movement of oil into shoreline and estuarine ecosystems as well as the anticipated effects of oil on shoreline and estuarine physics, chemistry, and biology. Although EPA and other agencies had much of this scientific information at their disposal, many key pieces of information were only known in general terms, available only from manufacturers, or related to large oil spills in ecosystems dissimilar to the Gulf of Mexico.

A key starting point for this research approach is to list anticipated decisions that will be made in the short-, intermediate-, and long-term by EPA and its collaborating Federal agencies and State/Tribal partners. EPA assumes that any research strategy will be integrated in a transdisciplinary way across agencies, as well as with States, academia, and the private sector (Figure 3-1).

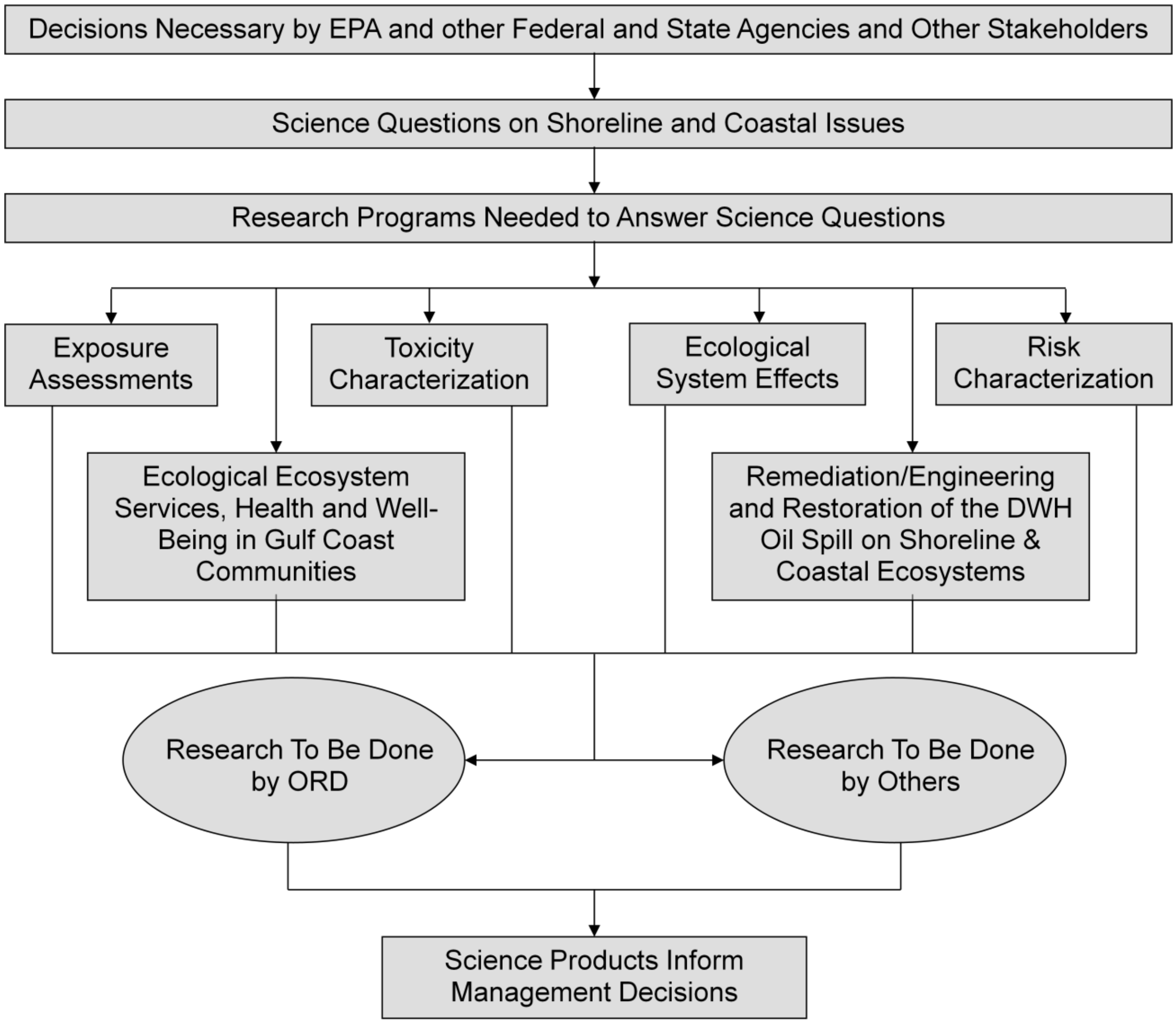

Figure 3-1 Shoreline, Coastal, and Inland Effects Problem Formulation and Research Development Framework

Anticipated Decisions Related to the Oil Spill

It is unrealistic to list all of the potential decisions made concerning the DWH oil spill in the strategy. It is reasonable, however, to examine example decision endpoints for short-, intermediate-, and long-term time lines. Examples of decisions to be made by EPA (OEM, Regions 4 and 6, the Office of Water), or other Federal agencies in the short-term (within the next year), to intermediate time periods (1-3 years), and long-term decision endpoints (> 3 years), are presented in Table 3-1.

The next step in determining what shoreline and coastal effects research, relating to oil spills, will be supported by EPA is to finalize the key science questions to be answered to inform the decision-making process effectively. As indicated in Table 3-1, this step is outlined by research areas (exposure assessment, toxicity characterization, ecological system effects, risk characterization, ecological system services, health and well-being in Gulf Coast communities, and remediation/engineering and restoration of the DWH oil spill on shoreline and coastal ecosystems). A parallel effort necessary to determine the research EPA will support is to identify the research currently supported by EPA and other Federal agencies or anticipated to be supported in the near future. The combination of the science questions required to inform the decision-making process, the existing and anticipated research, and the skills mix within EPA will determine those research programs/projects where EPA can have a significant, and perhaps unique, impact on the overall oil spill recovery and any future responses to oil spill disasters.

Table 3-1. Examples of Decision Endpoints

Short-term (within the next year)	Intermediate (1-3 years)	Long-term (> 3 years)
How should State and Federal permitting decisions on shoreline protection be addressed?	How should technical and financial resources be prioritized for restoration? Should the recovery process and progress be monitored and documented? How?	What are the best ways to determine the implementation and adaptive management of the Gulf-wide restoration? Geographically where? To what extent?
Can existing routine and new dredge sites that have received oil have their sediments deposited in existing dredge disposal areas?	How should restoration efforts in the Gulf of Mexico coordinate with existing Gulf of Mexico programs like Gulf hypoxia or other Federal programs (e.g., Coastal Wetland Initiative, 319 Programs, National Estuary Programs, and Coastal Zone Programs)?	What are the best long-term strategies for managing ocean dumping sites in the Gulf of Mexico that have been impacted by the oil spill? Should they be remediated? If so, how?
How will oil deposition affect existing or already approved wetlands mitigation banks and/or sites?	Should restrictions be placed on foods harvested from the Gulf of Mexico and its inland waters?	At what point is routine dredging in areas impacted by oil permitted to continue? Should active remediation programs be initiated? Should natural processes be the preferred remediation technique?
Should development projects that will re-suspend sediments/surface oil be approved?	Should designated ocean dumping sites be re-characterized? If so, how?	Should "protective" techniques employed during the DWH oil spill be permitted for use in any future oil-related disaster responses? For example, are there long-term impacts associated with the use of sorbent boom, hard ocean boom, controlled burns, dispersant use, containment curtains, and microbial degradation?
Should specific efforts to block, trap, or divert oil be permitted?	Should reference sites for monitoring in the Gulf of Mexico estuaries and coastal wetlands be re-characterized? If so, how?	To what degree have the ecosystem services of the Gulf of Mexico ecosystem been altered? How does the change affect the decision process? Can these services be restored by active remediation programs? If so, what programs would be successful and how is success measured?
What compensation should be sought for oil spill related immediate damages?	Should remediation efforts/programs be monitored? If so, how? For what purpose?	To what degree has the well-being of the inhabitants of the Gulf of Mexico region (as well as elsewhere in the United States) been altered because of the DWH oil spill? How does the change influence the decision process? Can well-being be restored to pre-spill levels by active remediation programs? If so, what programs would be successful and how is success measured?
Should a fishery/shellfishery in a given area be closed? Re-opened? Modified?	Should we find alternatives to near-shore and/or offshore dredge materials disposal? What are these alternatives (e.g., land farming, lined land disposal facilities, hazardous waste sites, underground containment)? How do we decide the priority of these alternatives?	
Should a given area be closed to commercial maritime traffic?	Should reproductive/developmental habitats for fish and shellfish be restored? How? Where? Which?	
What ecological systems/sub-systems should be remediated and how?	What requirements (ecological) should be imposed on new drilling sites?	
What measures will be used to assess the success of remediation/mitigation?		

b) Related Federal Research Activities

The research proposed for ecosystem services and human well-being clearly will be accomplished through collaboration between NOAA, NPS, FWS, and EPA. More specifically, the collaboration among these four organizations will assess the impact of the spill on coastal ecosystem services and the impact of the losses on the well-being of Gulf of Mexico residents. The research provides an important leveraging opportunity whereby EPA/ORD, NOAA's Ocean and Human Health Initiative (OHHI) and the NPS's National Resources Program Center (NRPC) can jointly examine the changes in ecosystem services and the well-being of residents of the Northern Gulf of Mexico region, including parklands (e.g., Gulf Islands National Seashore). Several toxicological effects research topics will be addressed through collaboration with academia. Finally, numerous monitoring and research efforts to examine the efficacy and success of remediation efforts will be proposed collaboratively with other Federal and State agencies. The EPA Administrator-led Ecosystem Restoration Task Force will also be an important collaborative partner.

c) Proposed Research Activities

The discussion of research topics within the area of shoreline and coastal effects has been subdivided into exposure assessments; toxicity characterization; ecological system effects; risk characterization; ecological ecosystem services; health and well-being in Gulf Coast communities; and remediation/engineering and restoration of the DWH oil spill on shoreline and coastal ecosystems.

1. Exposure Assessments

Decision Context	Key Science Question	Anticipated Outcome
Are dispersants or changes in oil chemistry effective in reducing exposure to oil and its constituents?	How do dispersants and changes in oil chemistry influence the movement of oil and its constituents through marine and estuarine ecosystems?	Completion of this research will improve understanding of oil movement in marine systems and will help to develop models that will inform managers.
	How can we improve the tracking and detection of oil movement in marine and estuarine ecosystems?	Completion of this research will allow better prediction of oil transport and the extent to which oil will contact ecological receptors.

Research to understand the influence of dispersants and chemical changes on oil transport

Understanding the effects of dispersants on the temporal and spatial profiles of exposure of pelagic organisms is key to making future decisions on the use of chemical dispersants. Research will improve the prediction of the movement of separate phase oil and the anticipated changes in the rates of dissolution/dispersion of oil constituents into the water column. Some of the processes that may occur include: (1) transport via advection and dispersion processes; (2) deposition and re-suspension of PAHs sorbed on particles; (3) volatilization of PAHs to the atmosphere (many PAHs are semi-volatile compounds); (4) transformation of PAHs by photoreactions and microbial transformations; and (5) weathering. Process-based models will integrate data and algorithms that describe these processes and carefully planned monitoring studies, which can be used to evaluate the model results and help refine the models.

Research to improve spatially explicit models to predict oil and constituent trajectory

Risk assessment models and decision support tools are typically based on the best available data at the time of development. Existing models, such as the Regional Vulnerability Assessment (ReVA) Program's Web-based Region 4 Environmental Decision Toolkit (R4-EDT) (USEPA, 2010d) are based on extensive environmental databases and have the potential for comprehensive risk assessment of both human and ecological populations. Exposure and assessment tools, such as ReVA, can be further developed using data collected from the oil spill to improve applicability to future spills.

2. Toxicity Characterization

Decision Context	Key Science Question	Anticipated Outcome
Will oil-contaminated sediments have to be remediated to mitigate risks to benthic organisms?	Are current ecotoxicity benchmarks for benthic organisms adequately protective of aquatic life? What is the toxicity of oil constituents and non-aqueous phase oil to benthic organisms?	This research will determine if oil contaminated sediments have to be remediated to mitigate risks to benthic organisms. Supports decisions on whether remediation can be confined to monitored natural remediation or whether remedial actions should be taken to restore sediments.
Does EPA need to modify the approach for setting aquatic life Ambient Water Quality Criteria (AWQC) for PAHs?	Are current ecotoxicity benchmarks and AWQC for PAHs adequately protective of aquatic life?	This research will address a primary area of uncertainty in the metrics EPA is using to calculate risk. This research will address an issue that has been missing thus far from EPA's effects assessment metrics for the DWH event.
Can EPA better monitor the exposure of aquatic life to dispersants and dispersed oil?	Are there unique genomic signatures to different oil types and weathering states? Can genomic methods be applied to oil spill monitoring?	This research may provide tools to inform managers on the exposure of aquatic life to dispersants and dispersed oil.

Research to understand the relative roles of the physical effects of oil on benthic organisms as compared to chemical effects from oil-associated PAHs

It is long-standing conventional wisdom that the aquatic toxicity of crude oil is related directly to the PAH component of the complex mixture of compounds present. Although this presumption appears well supported for water column organisms, recent research shows that for certain benthic organisms toxicity is more closely correlated to a non-aqueous phase (oil) than to the specific toxicity of PAHs. Because crude oils (and other oils released to the environment) vary considerably in their PAH content, modifications to ecological benchmarks intended to protect benthic receptors will address both elements of exposure/effects so that the intended level of protection is achieved.

Research to refine the approach to predicting chronic toxicity of oil constituents to aquatic organisms, particularly early life stages of fish

Current approaches for assessing the aquatic toxicity of oil constituents are based on a narcotic mode of action. Data from some literature indicate that toxicity to certain organisms, such as early life stages of fish, occurs through other toxicity mechanisms, resulting in an underestimation of toxicity by the current narcosis-based approach. Research activities will increase the understanding of the relative importance of these mechanisms, ensure that ecological benchmarks focus on the appropriate constituents of oil, and provide the desired level of protection of all ecological receptors.

Research to identify tools to understand the degree to which photo-enhanced toxicity of PAHs affects the risk of oil contamination to aquatic receptors

As mentioned above, current EPA procedures for deriving ecological benchmarks for oil components are based on a narcosis mode of action. This approach does not account for enhanced toxicity resulting from combined exposure to oil-associated PAHs and sunlight, the combination of which has been shown to produce much greater toxicity than do PAHs via the narcotic mode of action (which is light-independent). Improved approaches will quantify the additional risks that can be expected from photo-enhanced toxicity, and the circumstances (habitat, water clarity, temperature, etc.) under which those mechanisms are of greatest concern.

Research to develop omic tools to use aquatic organism responses for oil spill monitoring and remediation

Exposure to aquatic organisms from oil spills is typically inferred from measurements of oil constituents in media. Measurement of oil in biota is problematic because of selective bioaccumulation and biotransformation. Ethoxyresorufin-*o*-deethylase (EROD) is typically used but is nonspecific to petroleum hydrocarbons. This project would determine whether omic methods can be applied to determine whether biological signatures resulting from exposure to oil are unique, and whether these methods could distinguish oil types or weathering states. For example, proteomic responses to various types of crude oils and varying weathering states of crude oil from major spills, such as the DWH and Enbridge oil spill to the Talmadge Creek in Michigan on July 26, 2010, could be assessed. The objective would be to determine whether there are unique biological response signatures to crude, gas, diesel, and heavy oil. Oil types have been fingerprinted using analytical chemistry, but no methods exist that measure definitive indicators of oil contamination in biological organisms. The research will potentially provide EPA with a method to monitor sublethal responses to oil spills, including the potential to assess the spatial extent of impact and the success of remediation by monitoring the spatial and temporal distribution in omic responses.

3. Ecological Systems Effects

Decision Context	Key Science Question	Anticipated Outcome
Research to address this question will inform Federal decisions related to estimation of damages to natural resources and implementation of ecosystem-level restoration.	What ecological impacts have occurred in sensitive coastal ecosystems because of the DWH oil spill?	Understanding the direct and indirect effects of oil exposure on, for example, seagrass habitats and other vital habitats will contribute to the NRDA by quantifying impacts on a vital nursery habitat for fishery species.
How did remediation technologies in emergency response (i.e., oil spill) scenarios perform?	How well did different oil containment/remediation technologies prevent or reduce adverse impacts to sensitive coastal ecosystems?	Understanding the effects of oil exposure and remediation on the functions and services provided by coastal wetland habitats will contribute to the NRDA.
What remediation options have minimal impact on coastal and inland ecosystems?	What effects do activities (e.g., dredging, construction of shoreline protection structures) have on sensitive coastal ecosystems that were impacted by the DWH oil spill?	Determining the impacts of oil remediation technologies on coastal and inland ecosystems will enable decision-makers to choose the most appropriate remediation options based on scientifically sound information.

Multiple agencies are implementing monitoring activities to track changes in coastal ecosystem conditions in areas affected by the DWH oil spill. The ecosystems of concern are primarily estuaries, wetlands, and near-shore waters (beaches). The “tools” that EPA has historically employed to monitor ecosystem conditions (e.g., National Coastal Assessment survey designs, indicators) can be used to assess the conditions of coastal ecosystems prior to the spill and to track changes in conditions since the spill. However, since the DWH oil spill is an unprecedented event, many new uncertainties will be addressed. For example, existing data from varied sources can be used to establish baseline conditions for coastal ecosystems; however, additional research may determine: (1) the appropriate spatial and temporal scales for comparing conditions and assessing effects, (2) whether observed changes in ecosystem conditions are significant, and (3) whether observed changes in ecosystem conditions were caused by the spill. Additional research will assess the ecological effects of the DWH oil spill on sensitive coastal ecosystems.

Research to determine the effects of oil and oiling on specific receptors not well represented by existing data

The distribution of oil slicks across large areas creates the potential for exposure of many different habitats, some of which are characterized by species that are not commonly represented in toxicological literature. In addition, effects of oil contamination may result from both the toxicity caused by chemicals that dissolve from oil into water, as well as the by the coating with oil itself. Additional data will improve the understanding of the vulnerabilities of these under-represented taxa/habitats. Example taxa include coral, marsh grass, and seagrass.

Research to improve understanding of the effects of oil on submerged aquatic vegetation

PAH Exposure Direct Effects

Monitoring porewater PAH concentrations and fluorescence properties along with PAHs in the sediments would determine the flux of potentially toxic material at the sediment-water interface and inform assessments of the long-term effects of remobilization (re-exposure) on seagrasses. In shallow water seagrass habitats, oil components on the surface of the sediments can be degraded by sunlight through photodegradation or increased temperatures. Additionally, oil buried in the sediments can be re-mobilized by an episodic storm event and subsequently exposed to sunlight and photodegradation once again.

Oil Indirect Effects

The effect of small oil droplets (which border the dissolved and particulate pools) on light attenuation in the coastal zone is not well understood. Monitoring changes in light attenuation resulting from dispersed oil in the water column will inform researchers on the variation of underwater light field as a function of suspended oil droplets and how this affects seagrass primary productivity in the coastal zone.

Research to characterize the effects of oil, and remediation technologies on coastal and inland ecosystems

Wetland Function/Processes

Research will improve the understanding of whether exposure to oil inhibits or enhances wetland functions and processes, particularly those related to nitrogen cycling. The added petroleum could serve as a carbon and energy source to fuel denitrification and thereby alter the nitrate removal capacity of wetlands. The consequences of such alterations on surrounding waterbodies could be either positive or negative depending upon whether nitrogen is the limiting nutrient to plant and microbial communities, or whether it leads to elevated nitrate concentrations in water supplies (e.g., coastal groundwater, Lake Pontchartrain). On the other hand, exposure to the toxic components of oil could have negative impacts on microbial communities, thereby inhibiting microbial processes (e.g., denitrification, nitrification, and ammonification).

Coastal and Inland Habitats

Research will improve the understanding of the comparative effects of constructing sand barriers or other hard shoreline protection structures (e.g., rock, shell, sheet pile) versus deploying temporary oil/chemical containment technologies (booms, etc.) and structures on fish and wildlife habitat, sediment transport, and wave dynamics along the Gulf Coast, and their relative efficacy at abating shoreward movement of oil. Understanding the ecological effects of the various measures used to try to block and/or capture oil and related substances would help to evaluate Section 404 emergency response proposals and target the most effective measures. Each of the “protective measures” could be evaluated in terms of physical and chemical blockage/ capture of the various oil-related substances in different current regimes to determine the associated environmental/ecological effects.

4. Risk Characterization

Decision Context	Key Science Question	Anticipated Outcome
Does EPA have the appropriate tools for determining the ecological risks of spilled oil?	Can probabilistic modeling approaches be applied to assessing risks of spilled oil?	Completion of this research will help to improve probabilistic risk assessment approaches to inform risk management.
	Can tools be developed or applied to determine population level impacts of spilled oil?	Completion of this research will improve EPA's ability to assess and inform managers on population-level impacts of endangered and sensitive species, or other species of concern.

Research to ground verification of probabilistic modeling approaches for ecological risk assessment of aquatic organisms

Ecological risk is typically assessed by benchmark values derived from toxicity of a contaminant to sensitive receptors where exposure is likely to occur. Large-scale, landscape-wide impacts contain a gradient of exposure risk and heterogeneous community composition for which benchmark values of standard test species are hindered by large uncertainty. Probabilistic models that combine exposure risk, community structure, and species sensitivity will more accurately reflect ecological impacts of regions within the impacted area. Separate exposure and effects models have been developed from diverse datasets but have not been applied in large, landscape-wide situations and ground verification of combined models is lacking. Research will verify the predicted risk of combined exposure and effects models for aquatic populations in coastal ecosystems.

Refined population-level approaches for ecological risk assessment

Standard ecological risk assessment approaches are limited by their focus on organismal-level impacts. Development and application of refined population models for species of concern may be used to predict long-term ecological impacts to aquatic and terrestrial communities, assess the effectiveness of various mitigation practices, and predict impact to ecosystem services via loss/gain of population density.

5. Ecological Ecosystem Services, Health and Well-Being in Gulf Coast Communities

Decision Context	Key Science Question	Anticipated Outcome
How have ecological services been impacted by the DWH oil spill?	What are the likely losses of ecosystem services due to the DWH oil spill?	Completion of the ecosystem services and well-being project areas will permit a robust and inclusive assessment of the economic, ecological, and social (individual and regional) impact of the DWH oil spill. This assessment will inform an enumeration of the financial burden that should be placed upon BP.
How has human well-being that depended on ecological services been affected?	What are the likely degrees of impact on human well-being from losses of ecosystem services? What are the relationships between ecosystem services affected by the oil spill and individual and regional well-being? Can the losses in human well-being and ecosystem services be regained through remediation?	Understanding the direct and indirect effects of oil exposure on human well-being will contribute to the NRDA by quantifying the social and economic impacts of the spill.

Research to improve understanding of the impacts of the DWH oil spill on ecological services

The DWH disaster in the Gulf affords a unique opportunity to examine changes in the ecosystem services provided by Gulf of Mexico ecosystems. The values of ecosystem services are being established by the demands for compensation, including direct losses such as those in commercial fisheries and tourism, and indirect losses represented by compensation requests for mental health services and reduced donations to/increased demands on local charities. Assessing the loss of ecosystem services (e.g., shoreline protection by wetlands, coastal fisheries, and recreational opportunities) due to the DWH oil spill will be a major effort of the NRDA. While EPA is not directly involved as a Trustee in the NRDA, a collaboration between EPA, NOAA, and NPS will assess the impact of the spill on coastal ecosystem services and the impact of the losses on the well-being of Gulf of Mexico residents. Such a collaboration is under investigation by the three agencies and will provide an established baseline of ecosystem services (e.g., what level of services [amount, value] were provided by wetlands, estuaries, open water, and beaches prior to the spill). Ecosystem service indicators will be assessed and monitored at a spatial and temporal scale designed to detect changes in the level of service provision since the spill. Most importantly (but also the most difficult), any detected change in ecosystem services will be linked to (i.e., caused by) the oil spill, eliminating other causal factors like climate, fishery closures not due to the spill, and developmental pressures.

As an example, one ecosystem to examine for changes in ecosystem services is coastal wetlands. Wetlands perform many key ecosystem services that are potentially at risk due to the oil spill associated with the DWH explosion. The key to understanding the effects of oil and dispersants on wetland processes is the ability to characterize the baseline ecosystem services provided resulting from the interactions of differing types of wetlands and environmental conditions along the northern Gulf of Mexico. The condition of Gulf of Mexico wetlands will be assessed in terms of ecosystem conditions in 2011 using EPA's National Wetland Condition Assessment USA-Rapid Assessment Method. The magnitude of the ecosystem services provided by wetlands can be estimated using ongoing modeling efforts to elucidate the relationships between elements of wetland conditions and the provision of services. In addition, specific wetlands along gradients of environmental conditions can be assessed for nutrient and carbon storage capacity through soil coring and laboratory analyses, and nutrient processing through *in-situ* and/or laboratory studies of phosphorus and nitrogen assimilation/sequestration/ transformation rates. Data collected will be incorporated with representative spatially explicit information of wetland types and influential landscape characteristics so that the resulting spatial models can be transferred to estimate the ecosystem services in the Northern Gulf of Mexico, while also providing baseline information to contrast oil-affected systems with those lacking such impacts.

One of the primary objectives of the ecosystem services research will be to utilize remote sensing, Geographic Information Systems (GIS), and landscape ecological theory to produce baseline digital maps of wetlands, estuarine, beach, and open-water ecosystem services, and the associated base data layers, in the coastal zone of the United States. Using standard GIS methodologies and demographics, these estimates of ecosystem services can be distributed among the affected ecosystems to estimate unit (e.g., acre) values. Short- and long-term future scenarios can be built based on estimates of recovery times and used to estimate total costs for this singular incident. Scenarios can later be further refined to incorporate results of remediation and restoration research projects.

Research to determine the impacts on human well-being resulting from the DWH oil spill

Changes in services for estuarine, wetlands, open-water and beach ecosystems correspond to attendant changes in the well-being of the inhabitants of the Gulf of Mexico coast. Translating changes in ecosystem services into dollars lost or gained, ecological units lost or gained, and increases and decreases in human well-being will be a major research effort for EPA that will address specific decision endpoints. This research area provides an important leveraging opportunity whereby EPA/ORD, NOAA/OHHI, and NPS/NRPC can jointly examine the changes in ecosystem services and the well-being of residents of the Northern Gulf of Mexico region, including parklands (e.g., Gulf Islands National Seashore).

A baseline of well-being will be constructed from indicators that include health, environment, subjective well-being, and economics from secondary data that are available from all of the Gulf coast counties as well as surveys designed to collect otherwise unavailable information. Using these social science data, a joint research effort will establish baseline indicators of both actual and perceived health and well-being in coastal counties. Indicators of ecosystem conditions and services provisioning will be integrated with social science data to provide an overall picture of health and well-being and document changes to Gulf coast communities as they persist and adapt through the impacts of the DWH disaster. Collaborative research will produce metrics to assess the degree to which restoration of biological and physical resources and associated ecosystem services contribute to the restoration of human well-being in the region, help prioritize restoration activities that will contribute to well-being, and identify social structures and institutions that may need attention to assure successful environmental restoration. Remediation research, activities, and monitoring will be closely coordinated with other Federal and State agencies, including NOAA, NPS, USGS, and State resource agencies.

6. Remediation/Engineering and Restoration of the DWH Oil Spill on Shoreline and Coastal Ecosystems

Decision Context	Key Science Question	Anticipated Outcome
Are new oil/chemical containment technologies/options being developed to help contain potential future spills?	What innovative tools will be developed for oil spill containment, remediation, and restoration?	This research will provide critical information to regional decision-makers concerning the approval of approaches for the use of engineering options for oil containment.
What is the most effective suite of remediation/cleanup technologies/options?	What innovative tools will be developed for oil spill cleanup to enhance the effective suite of remediation/cleanup options?	This research will provide important information to decision-makers when selecting remediation options for local wetlands, beaches, or coastal waters.
What is the most effective suite of restoration technologies/options?	What innovative tools will be developed for restoration after an oil spill to enhance the effective suite of remediation/cleanup options?	This research will provide important information for decision-makers in determining whether to actively restore a specific impacted location or to let natural processes restore the area.

Research to identify innovative tools for oil spill containment, remediation, and restoration

The DWH oil spill is an event that is extensive in size and complexity. The challenges faced in the engineered damage prevention, remediation, and restoration of such an event are unprecedented in the United States. However, other large spills worldwide have provided situations where information that directs these three areas can be utilized as a starting point for proposed current and future research efforts. Proposed research will look to develop a suite of rapidly deployable procedures, both new and existing, in all three of these areas that have high confidence of performance success with known levels of uncertainty of the potential for unintended consequences (e.g., environmental degradation). The engineering, remediation, and restoration efforts will closely communicate and interact with the ecosystem effects and toxicity efforts in order to understand potential outcomes (e.g., ecosystem effects) and risks for unintended secondary consequences (e.g., toxicity). Although it is hoped that such a large-scale spill will not occur again, the possibility of smaller, more localized spills still remains high, not only in the Gulf of Mexico region, but in all areas where oil transportation, storage, or production are occurring. The successful development of these innovative technologies, coupled with an understanding of their limitations, will allow any future deployment in response to oil spills to be accomplished more rapidly and with greater levels of certainty regarding what can be implemented effectively.

Proposed research will assess the potential engineering, remediation, and restoration technologies, both innovative and existing, in response to the DWH oil spill on shoreline and coastal wetlands and ecosystems:

Washing of oil from surfaces and plants

A test protocol has been developed for evaluating surface washing agents applicable to solids such as rocks and sand. Additional research will be conducted to evaluate the performance of washing, with and without detergency additives, on surfaces and on plants. Research will also evaluate whether or not higher-pressure washing can move oil from wetlands to open areas where it can be treated or removed.

Addition of oxygenators to degrade oil

Research to determine if oxygenators can be added to the oils to help facilitate the breakdown of oils into less toxic components that can be attenuated by the system. This research will apply findings from *in-situ* chemical oxidation processes applied to soil and ground water to beaches and wetlands.

Bioremediation

Natural weathering of oils in marshes. Research will evaluate the natural weathering of oil in wetlands and determine if the assimilative capacity of natural processes will remove oils in a less destructive way than traditional remediation. The research will include characterization, mechanistic studies, and modeling to develop multiple lines of evidence for natural recovery, similar to the research conducted for monitored natural attenuation in ground water and monitored natural recovery in sediments. This work will be conducted in collaboration with USGS, U.S. Army Corps of Engineers (USACE), and NOAA.

Fertilization: Addition of nitrogen and/or phosphorus to produce natural surfactants.

Research to determine if the addition of nitrogen and phosphorus or phosphorus alone can enhance the biogenic production of natural surfactants. If so, research will evaluate if the quantities will have any appreciable effect on the oil *in-situ*. Research will evaluate nutrient loading and delivery methods. For heavily contaminated areas, research on a prepared-bed treatment may be a viable option to contain and treat the source. Alternatively, for zones where oxygen is depleted, inexpensive methods of delivering oxygen are needed. Field evaluations will be undertaken to: (1) assess the assimilative capacity of the wetlands as a function of the extent of oiling, oil composition, vegetation, and redox conditions, especially as influenced by hydraulic pumping; (2) after identification of specific environments amenable to biodegradation, assess the use of nutrients in accelerating the rate of degradation; and (3) assess the ecological response to both passive and active assessments. This work will be conducted in collaboration with USGS, USACE, and NOAA.

Phytoremediation: Using plants to degrade oil. Phytoremediation may have a role in certain coastal areas. Its effectiveness depends upon a number of factors including the extent of oiling, indigenous vegetation, and needed rate of recovery. The brackish environment along with the toxicity associated with the oil present difficult conditions for plant growth. Recent initial research conducted under these conditions has demonstrated success in using this process to treat petroleum contamination in brackish conditions (Greenberg et al., 2007). Field research will evaluate the utility of this process.

Research to improve the understanding of restoration options to restore conditions of affected shorelines and wetlands to a desired condition that supports the provision of sustainable ecological services

Natural Restoration

Evaluation of the restoration of various biotic components of the system will determine what recovers and how fast this recovery occurs. Evaluation of potential seed banks will provide an indication of what the potential for restoration recovery may be in each system.

Enhanced Restoration

Evaluation of how active "seeding" of the system with flora and fauna typical of these systems may accelerate the restoration of these systems to a desired condition.

d) Progression of Research Activities

The proposed research strategy illustrates the problem formulation developed for coastal, shoreline, and inland impacts that identifies the specific science questions and subsequent research activities, which will ultimately inform management decisions. The research on coastal and shoreline impacts includes exposure assessment; toxicity characterization; risk characterization; ecological system effects; ecosystem services, health, and well-being in Gulf Coast communities; and remediation/restoration of the DWH oil spill on shoreline and coastal ecosystems. Figure 3-2 illustrates the progression of coastal, shoreline, and inland impacts research from FY 2011 through FY 2015.

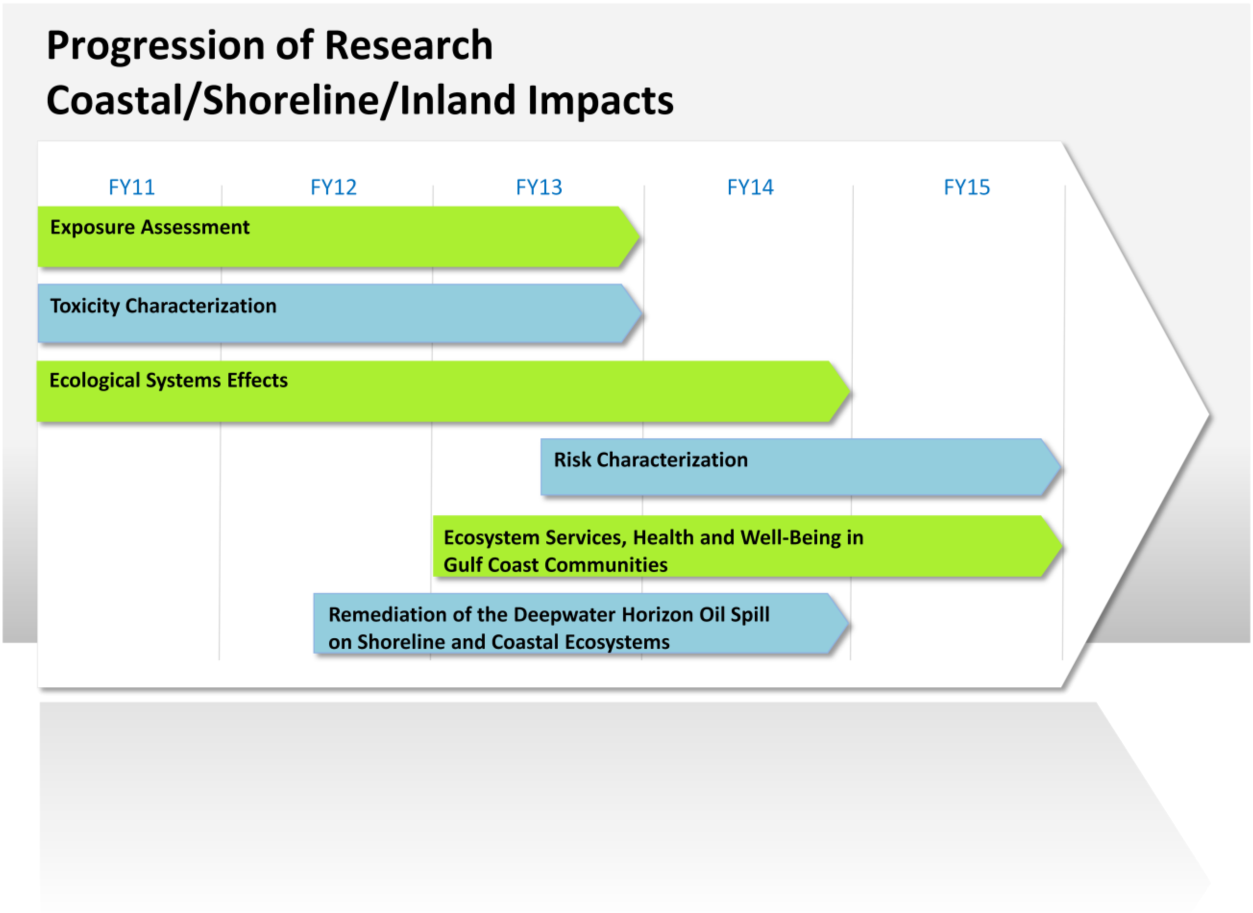

Figure 3-2 Progression of Coastal, Shoreline, and Inland Impacts Research

4) Innovative Processes and Technologies Development

a) Problem Formulation

Over the last two decades, EPA's research has resulted in new protocols for testing the effectiveness of commercial oil spill treating agents (bioremediation products and dispersants), guidance documents for implementing bioremediation in different environments, a clearer understanding of the impact and persistence of non-petroleum oil spills in the environment, and development of new spill treatment approaches. Figure 4-1 describes a framework to assess innovative processes and technologies in various environments and with existing and alternative fuels. Open water treatments prior to the DWH spill were generally targeted at spills from tankers, with a finite quantity of oil spilled at or near the water surface. EPA now knows that response technologies need to be available for deep, sustained, high-pressure flows of oil, in addition to spills from tankers and inland spills. Options will include mechanical collection, physicochemical treatment, and bioremediation. They will address fresh oil, emulsified and dispersed oil, and heavy residuals on the floor of the water body, in the water column, at the shoreline, and inland. Work undertaken in open waters, especially deep waters, will be conducted in concert with other agencies with primary responsibility for these areas. Research applying green chemistry/technology principles will be conducted on the development of effective oil spill remediation technologies. The research will inform regulatory actions and result in technology transfer activities to communicate effective methods.

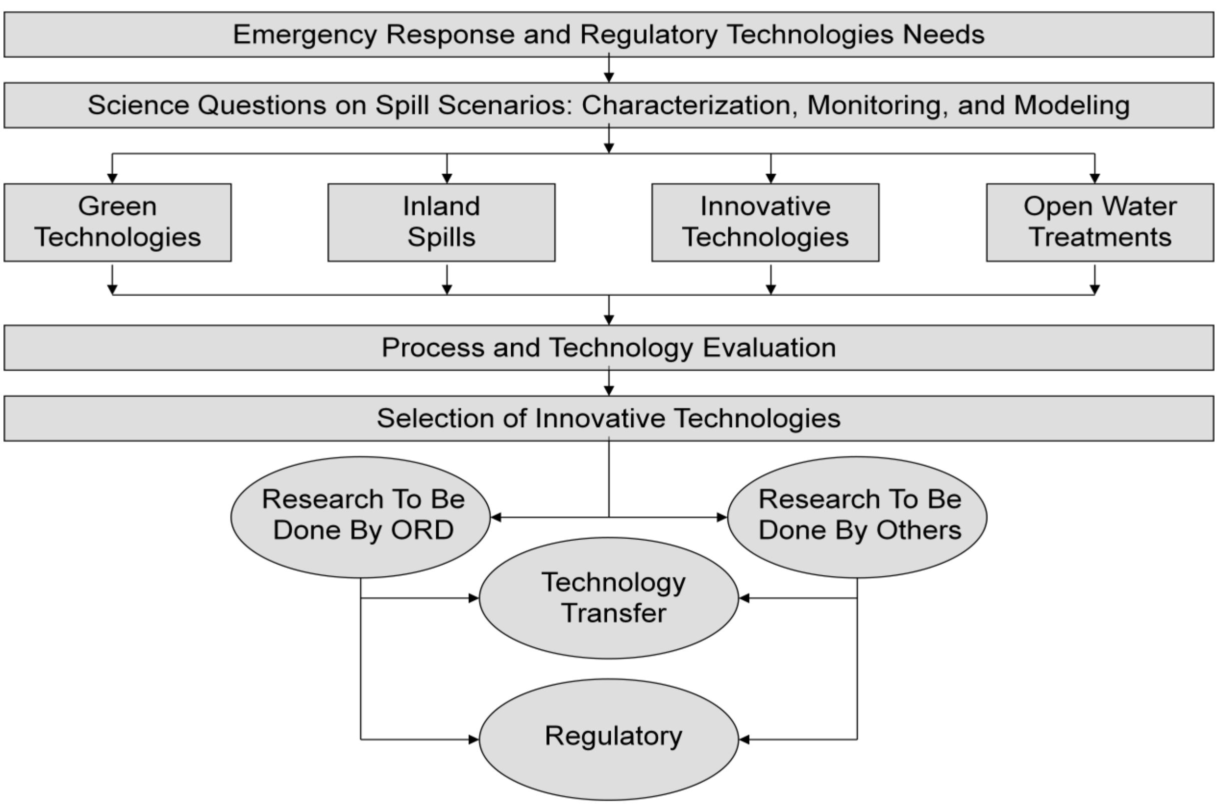

Figure 4-1 Innovative Technologies Problem Formulation and Research Development Framework

b) Related Federal Research Activities

At least four research activities and/or grant programs were instituted during the DWH oil spill. They are briefly described below.

Since the early days of the DWH spill, individuals and organizations have submitted thousands of suggestions related to response and restoration to an interagency work group, the Interagency Alternative Technology Assessment Program (IATAP), of which EPA is a member. The Coast Guard and BP set up groups and processes to review the technical merit and applicability of the submittals for possible incorporation into response and remediation activities in the Gulf (RestoretheGulf.gov, 2010).

The NSF used their Rapid Response Research Grants program to solicit largely academic research relevant to the DWH spill. Some of the awards were for research on conventional and innovative response approaches (NSF, 2008).

BOEMRE manages research associated with renewable energy, oil and gas operational safety, and oil spill response (DOI, 2010a). Additionally, OEM administers Ohmsett – The National Oil Spill Response and Renewable Energy Test Facility (DOI, 2010b). BOEMRE's oil spill research program issued a broad agency announcement seeking research white papers/ proposals. Most of the nine topics address innovative mechanical technologies to capture, contain, or otherwise manage spilled oil at high volumes in deep water settings (DOI, 2010c).

NOAA's research for spill response and restoration science is implemented through the CRRC, a partnership between NOAA and the University of New Hampshire. The use of alternative response technologies (e.g., *in situ* burning or the use of dispersants) remains an area of active research. Currently, CRRC does not have a solicitation open for additional oil spill research.

c) Proposed Research Activities

EPA will use its grants program, in-house research program, technology verification program, and adaptive management capabilities to develop and evaluate innovative technologies or processes for oil spill response. EPA will work closely with other agencies to leverage resources and ensure that the field trials incorporate metrics for capturing harmful environmental side effects and to work toward the restoration of the affected environments.

1. Deep/Open Water Treatment Technologies/Processes

Decision Context	Key Science Questions	Expected Outcome
What technologies are effective for petroleum spills in deep sea waters?	What physicochemical and biological processes and agents are effective on pressurized oil at depth, oil in the water column, and surface oil and oil emulsions?	More response options with a better understanding of both performance and environmental risks.
What technologies are effective for petroleum spills in deep sea waters?	How can negative environmental or human health effects of these technologies or processes be identified in advance to better engineer future applications?	More response options with a better understanding of both performance and environmental risks.

Research to identify effective biological and chemical/physical technologies for deep sea treatment

Biological

<u>Research to assess the of biodegradability of tar balls, emulsions, and dispersed oil</u>

Aerobic biodegradation can be an effective technique to transform contaminants (e.g., hydrocarbons and PAHs) to less toxic compounds such as CO_2 and water. In areas of high oil concentration, oxygen is often depleted by an initial burst of aerobic biodegradation. Anaerobic degradation, however, is much slower. Similar to aerobic bioventing in soils, techniques that introduce oxygen into water without volatilizing oil contaminants would be useful to relieve the oxygen depletion and speed contaminant removal. A floating platform, which could introduce air into the water column through a network of membranes, would be one method to achieve this goal. If air could be supplied by a compressor fueled by a solar panel or other renewable energy source (wind or wave powered), these units could be deployed more freely. The units would be sized to tolerate wave action without tipping. The research will include a cross-agency effort, including EPA, NOAA, and USCG.

<u>Research to evaluate treatment technologies to stimulate biodegradation of sub-surface residual oil and oil-in-water emulsions</u>

In addition to oxygen, research will determine the identification and delivery of nutrients or other additives to encourage microbial activity. These agents will depend on the spill setting, native microbial populations, and the state of the residual oil. Laboratory experiments will identify the potential benefits of nutrients or other additives, simulating appropriate environmental conditions such as temperature and pressure.

Physical/Chemical

<u>Research to identify sorbent materials, booms to prevent and contain contamination</u>

Research will devise innovative sorbent materials and sorbents in containment devices (e.g., silt curtains or sea floor mats) that can contain oil closer to the source or retain heavy residuals after the spill has been controlled. Research will also evaluate how effective freely dispersed sorbents on the oil bind and transform the oil to a condition where it is more easily removed with skimming techniques. Sorbent materials could also be incorporated, for example, in a curtain to protect wetlands and other key areas including populated areas, ecologically sensitive areas, or intakes for community water supplies. The design of these materials will combine functional characteristics of silt curtains and booms but will be composed of sorbent material deployed vertically. Finally, research will assess ways to reuse or recycle these materials as well as assessing methods for treatment prior to defining optimum methods for their disposal.

Research will examine innovative ways to treat and/or dispose of water from skimming operations. For the DWH oil spill, this water was managed in a number of ways including deep well injection. Consideration will be given to lifecycle costs and effectiveness of treatment/disposal.

Research will also be conducted on reuse options for booms. Significant quantities of boom materials were required in the recovery operations in the Gulf of Mexico region. Methods will be investigated for the reuse of these materials in recovery operations or other alternative uses prior to disposal.

In consideration of the physical/chemical treatment approaches, a lifecycle assessment will be conducted including the materials, effectiveness of treatment, by-product management, and ultimate disposition.

<u>Research to identify floating and sinking oil</u>

Some oil from the DWH spill may be migrating in plumes at depths where it is very difficult to collect or treat. Research will investigate ways to use various biological and/or physicochemical approaches to treat the oil at various depths through the vertical profile. Liquids separation and minerals processing science may be adaptable to this application. Air sparging and density gradient fluids will be evaluated.

<u>Research to evaluate thermal treatment in open waters and on shipboard</u>

Oil spill treatments with thermal processes include open water burning and shipboard incineration. EPA has completed a preliminary evaluation of dioxin formation from *in situ* burnings in the Gulf of Mexico. Further research will assess the effectiveness of combustion as a function of the type of oil and the resulting emissions. Research will be conducted on the effectiveness of mobile incinerators at sea or onboard incinerators to manage the large volumes of oil and contaminated debris generated from spill response activities (e.g., the saturated boom materials that are currently being sent to landfills). Recent research developments using mobile units that include energy recovery and improved air pollution control devices will be considered.

Research to improve the understanding of the impacts of remediation options

Biodegradation

Laboratory experiments will identify and assess any deleterious side effects of utilizing oxygen and nutrients to stimulate microbial activity as a treatment technology for subsurface residual oil and oil-in-water emulsions. Subsequent field research will verify performance and investigate cost-effective delivery methods.

Thermal Treatment

Research evaluating the use of controlled winter burns will include an assessment of the ecosystem service values before and after impairment and during recovery; evaluation of the optimal timing and location to execute a controlled burn with respect to the ecosystem, tidal influence, reoiling potential, and combustion conditions; and evaluation of air emissions and residuals from combustion. Initial in-house studies will use pilot-scale equipment for simulating the open burn conditions in the field to evaluate combustion conditions on hazardous air pollutant emissions. Marine and brackish conditions have the potential to reduce combustion temperature and effectiveness and to generate partial combustion products including chlorinated dioxins. The impacts of solid residues produced from these open burns on the marine and wetland ecological systems are also important and will be investigated. Information provided from the research will be used for evaluating the environmental risks and benefits associated with this approach for mitigating oil spill impacts. The work will be conducted in collaboration with the USACE and USGS and will include field monitoring if controlled burns are used in the DWH response.

2. Develop Inland Spill Mitigation Technologies

Decision Context	Key Science Question	Anticipated Outcome
What new or enhanced technologies are effective for inland spills?	How effective is the technology and does it have any environmental side effects?	Better or faster responses to inland spills.
Are these technologies applicable to non-petroleum oils, notably alternative fuels?	Do alternative fuels behave differently when spilled and do they respond to the same remediation approaches?	Better preparedness for spills as alternative fuels become more significant in inland transportation.

The major source of the largest inland oil spills in the United States is from ruptured pipelines and above-ground storage tanks. For example, the July 26, 2010 Enbridge oil spill to Tallmadge Creek in Michigan illustrates that inland spills can be significant in size, frequency, and impact on people and ecosystems. The response, as in most inland spills, relies on booms for containment, collection, and offsite disposal of oil along with contaminated soil and debris. Little is known about the effect of spills of biodiesel, emerging biofuels, or by-products from their manufacture on watersheds. Research is vital to continue to find effective ways to respond to both traditional petroleum spills and spills of non-traditional, alternative fuels and fuel blends. The development of innovative technologies will accelerate the response and reduce the high volume of waste generated in the process.

Research to identify effective enhanced technologies for inland spills

Initial response

Research will focus on physical containment of spilled oil in ways that capture more oil quickly and reduce the amount of waste requiring offsite disposal.

- Amendments added to agglomerate the oil on the water will reduce its spread and recover it with a significantly reduced water volume. This approach has the added advantage of reducing air pollution from volatilization of the lighter oil fraction.

- It may be possible to design booms and silt curtains to retain more oil than they currently do. Protective barriers are needed for shorelines in advance of spill migration.
- Spray-applied, naturally degradable materials would allow rapid deployment and generate minimal waste.

Post-spill remediation

Significant oil can remain at the surface and in the water column after initial spill response activities. Contaminated material can also be found in the surface sediments, particularly the heavier oil components that resist degradation.

Research to assess enhanced bioremediation of residual oil

Oil provides excess carbon in aquatic systems and shorelines; therefore, nitrogen and phosphorus may be required to balance the carbon/nitrogen/phosphorus ratio to improve active or passive biodegradation. Oleophilic fertilizers were used to treat shorelines in Prince William Sound from the Exxon Valdez spill (Pritchard et al., 1992), where the shoreline was principally composed of cobbles and rocks. Other forms of nutrient delivery can be effective depending on the composition of the shoreline material. Research will assess a prepared-bed treatment for heavily contaminated areas as a viable option to contain and treat the source. Alternatively, research will determine new ways to enhance airflow to stimulate microbial activity for zones where oxygen is depleted.

Research will evaluate phytoremediation, which may have a role in certain shore and near-shore areas. Its effectiveness depends upon a number of factors including the extent of oiling, indigenous vegetation, and needed rate of recovery.

Research to evaluate sorbents for contaminated sediments

ORD is working jointly with the Great Lakes National Program Office (GLNPO) and USACE's Waterways Experimental Station on further evaluation of sorbents for active cap material. The purpose of this research is to develop and evaluate high-capacity sorbents for use as active sediment capping materials for sequestering organic and inorganic compounds and using various tools to predict performance. Sorption capacity will be determined for mobile compounds or contaminants of concern such as PAHs; benzene, toluene, ethylbenzene, and xylenes (BTEX); and mercury in contaminated sediment so more representative sorption values and reactive life estimates can be used in capping design models. In addition, the performance of these sorbents in extreme hydrogeological conditions (high advective rate) or water chemistry environments (salinity, anoxic) will be determined. Research using these principles and executed specific to conditions in the Gulf will provide an approach to contain and immobilize the contamination.

For areas with higher concentrations of pooled residual oil, research covering the use of sorptive mats will evaluate the acceleration of the isolation of the oil, potentially improving the effectiveness of other forms of treatment such as bioremediation. These sorbents may include materials such as bagasse, peat moss, kenaf, or rice hulls or synthetic materials, as currently used in oil spill response or other applications. The type of sorbent used may depend upon a number of factors, including the specific environment for use and the nature of the contamination.

Enhancing oil removal using sorptive materials may result in improving the technical and economic effectiveness of the overall treatment approach. Research on the use of natural sorbents has already shown some success. The attraction of this approach is that the natural sorbent would wick the oil out of the anaerobic subsurface of a wetland or salt marsh and transport it to the surface where oxygen is available to encourage aerobic biodegradation. Eventually, the natural sorbent would itself biodegrade.

More generally, research on sorptive processes will assist in assessing the extent of containing oil-contaminated wetlands. In addition, research on sorptive approaches will evaluate their use in conjunction with other treatment processes/technologies to provide overall improved treatment effectiveness.

Research has been ongoing for several years concerning the biodegradability of biodiesel blends (B0 to B100). The biodegradation picture is complicated because the feedstocks (fatty acid methyl esters of soybean oil, sunflower oil, etc.) may have various degrees of unsaturation associated with their composition. The fewer the double bonds, the more difficult it is to biodegrade the oil. Also, double bonds in the presence of oxygen may cross-link and form polymers that are resistant to further biodegradation. These relationships will be thoroughly assessed to inform responders on how to best treat such spills in inland waterways.

3. Green Technology

Decision Context	Key Science Question	Anticipated Outcome
What short-term and long-term environmental costs are associated with production and use of the response technology?	What metrics can be used to assess and compare the environmental footprints of innovative response approaches? How can the response technology be changed to reduce its environmental footprint? Can waste streams be minimized or managed more effectively?	Government and industry decision makers will take into account environmental harm as well as remediation performance. Technology developers will consider life cycle factors in designing their products.
How can green chemistry/technology principles be applied to oil spill remediation technologies?	What innovative cleanup methods can be developed using green chemistry/technology approaches, incorporating a life cycle approach?	Development of effective technologies with a limited cost to the environment and human health.

Research to design innovative and more benign (green) approaches to address oil spill mitigation and remediation

OSWER developed principles for greener cleanups (USEPA, 2009) that are applicable to oil spills. In addition to the protection of human health and the environment, research will assess cleanup decisions on air pollution and water resource impacts from a given treatments as defined in the previous section. This will include an assessment of materials management to define ways to reduce wastes produced from the cleanup. Research will include an evaluation of the innovative biological, chemical, and physical treatment technologies identified.

This research will develop metrics to evaluate the environmental footprint of innovative technologies in development, testing, or verification. Life Cycle Assessment (LCA) principles will be used in the framework for judging the relative impact of conventional and innovative responses. Characterization and management of waste streams from the cleanup is an important part of the overall assessment.

4. Evaluation Process for Technologies

Decision Context	Key Science Question	Expected Outcome
What technologies and products should be used for a particular spill? How should small business and other vendor innovative technologies be evaluated to determine whether they are effective?	What tests should be used to predict both performance and detrimental side effects of technologies and methods? How will innovative processes/technologies be considered in an adaptive management approach?	Validation of new processes/ technologies for treatment of oil spills that incorporate adaptive management.

The ultimate utility of a process or technology is dependent upon the reduction in risk to human and ecological receptors. The monitoring and modeling programs during and after the DWH response activities will provide real-world data on the efficacy of mechanical, physicochemical, and biological remediation processes applied to a deep water spill. The Exxon Valdez accident and other spills that were studied in the 1990s (e.g., sandy shoreline in Delaware) and early 2000s (e.g., freshwater wetland in Quebec and salt marshes in Nova Scotia) provided similar data on remediation performance for a surface spill. In the absence of such spills, modeling and surrogate test methods will be developed and used for processes applicable at future spills. Finally, consideration will be given on how to utilize these innovative approaches incorporating adaptive management.

Research to develop test protocols for remediation agents

Research will continue to develop efficacy and toxicity tests to provide a better assessment of spill response products for application during and after an oil spill. The NCP Product Schedule currently lists 75 products for which data have been submitted in accordance with Subpart J of the National Contingency Plan (NCP, 40 CFR 300.920 (e)). EPA makes no value judgment on the applicability of these products, which include 35 surface washing agents, 15 bioremediation agents, 14 dispersants, and 7 solidifiers. The NCP specifies certain test protocols for the performance of bioremediation agents and dispersants, but the tests are conducted at the bench scale and cannot adequately mimic the wide array of oil types and spill scenarios. For example, deep water application of dispersants to a high-pressure oil stream was not envisioned in the test protocol. Subpart J requires toxicity testing for dispersants, but the questions raised during the response to the DWH spill suggest that open questions remain. Subpart J has a section reserved for toxicity testing of bioremediation agents, but no tests have been promulgated. A protocol has been started for surface washing agents and solidifiers. Research will be expanded to develop protocols for other agents.

5. Technology Transfer

In order to disseminate the results of EPA's oil spill research, strong linkages must be created and maintained between the researchers and developers and the technology users, including communication and coordination among all sectors. The distribution of information includes processing and evaluating invention disclosures, patenting technologies, marketing technologies, licensing, evaluation of new technologies, and training and seminars for Federal and State responders. Thus far, EPA's oil spill research has been shared through journal articles and presentations at national and international conferences, which aids in reaching out to both the research and practitioner communities. In addition, key products from the research supporting OEM regulatory activities are posted directly on EPA's oil spills Web Site. Accepted test protocols are published in the *Federal Register*. As EPA continues to develop research products and innovative technologies, the information will be circulated appropriately to ensure that it is shared with a wide range of users most effectively.

d) Progression of Innovative Processes and Technologies Research

EPA recognizes the need to increase research on the potential risks to human health and the environment resulting from oil spills. The research strategy illustrates the problem formulation developed for innovative technologies development that identifies the specific science questions and subsequent research activities that will ultimately inform management decisions. The research on the development of innovative technologies includes deep/open water treatment technologies/processes, inland spill mitigation, innovative technology evaluation processes, and green technologies. Figure 4-2 illustrates the progression of innovative processes and technologies development research from FY 2011 through FY 2015.

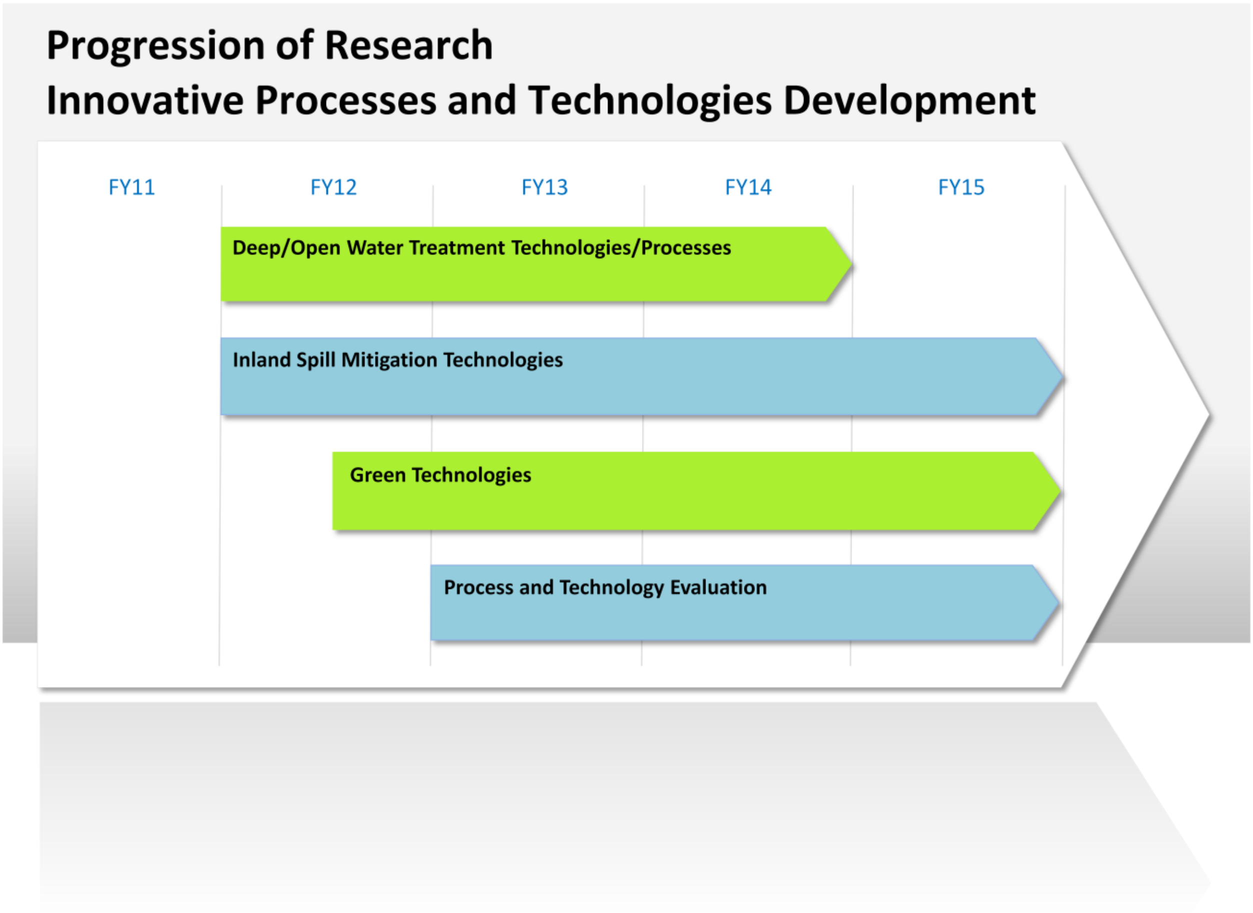

Figure 4-2 Progression of Innovative Processes and Technologies Development Research

5) Human Health Impacts

a) Problem Formation

Health problems among oil spill cleanup workers have been documented for more than twenty years with various oil spills including: the Exxon Valdez spill off the coast of Alaska in 1989 (Aquilera, et al., 2010), the Sea Empress tanker spill off the coast of Wales in 1996 (Lyons, et al., 1999), the Nakhodka tanker spill in the Sea of Japan in 1997 (Morita, et al., 1999), the Prestige tanker spill off the coast of Spain in 2002 (Bosch, 2003; Suárez, et al., 2005; Zock, et al., 2007), and the Tasman Spirit tanker spill off the coast of Pakistan in 2003 (Meo, et al., 2009a and b). Although the percentages vary, a common set of symptoms appear among a significant number of the workers, especially those who were not wearing respiratory protection or protective clothing. The symptoms include headaches, rashes, eye redness, respiratory problems, nausea, abdominal pain, and psychological disorders (e.g., anxiety and a sense that the spill has adversely affected their health) (Aquilera, et al.,2010). Most importantly, some follow-up studies several years after the initial exposure found increased frequencies of respiratory symptoms in local fishermen who participated in cleanup efforts, suggesting the presence of persistent respiratory effects (Zock, et al., 2007). In addition, the results of one study found that exposure for more than 15 days resulted in a significant reduction in lung function (Meo, et al., 2009b).

The DWH oil spill may have resulted in exposure of workers to concentrations of oil-related pollutants for a much longer period than in the aforementioned studies. Additionally, based on the earlier studies it has been recognized that exposure to some oil components, such as particulate matter (PM), results in adverse cardiovascular effects more so than respiratory effects (Burgan, et al., 2010). Yet, there are few, if any, studies examining cardiovascular effects of individual exposure to smoke plumes from burning unprocessed oil. Workers exposed to high levels of volatile organic compounds (VOCs) evaporating from oil dispersed on the ocean surface are a well recognized cohort that have been studied for respiratory and neurological effects (Aquilera, et al., 2010). However, these volatile compounds are also capable of forming secondary organic aerosols and traveling long distances where they, as well as smoke plumes, may affect nearby residents. This exposure likely includes more susceptible populations than cleanup workers such as pregnant women, the elderly, and those with cardiovascular or pulmonary disease.

There is limited but informative literature on the genotoxicity of oil and emissions from burning oil. The studies identified the polar compounds in the neutral fraction as the most mutagenic. One study with Prudhoe Crude from Alaska found that the material that precipitated on the land after burning the oil was twenty times more mutagenic than the original crude oil itself (Sheppard et al., 1983). Studies of the collected PM from the oil fires showed that on a mass basis, such PM had a toxicity profile similar to that of PM collected from typical city air. However, the concentration of PM was much higher per cubic meter in the oil fires, leading to some short-term health effects. One study documented a dramatic rise in adverse effects on reproduction and pregnancy in women immediately after the Gulf War in 1991-1992 (Makhseed, et al., 1999). However, various factors could have played a role in this beyond exposure to reproductive toxins from oil and oil fires.

Given the unresolved questions surrounding exposure to oil-related contamination, the goal for additional health effects research is to better define the pathophysiological pathways by which unprocessed oil, its components, and dispersants can cause adverse health effects in humans. EPA will partner or lead focused efforts on susceptible populations' exposure health effects as well as risk assessment and risk communication to affected communities. Short- and long-term follow-up epidemiology studies on workers involved in cleanup activities, as well as nearby residents, are an important research area. EPA assumes, at this stage of research planning, that the NIEHS-led epidemiologic studies of oil spill cleanup workers and volunteers will address many of the science issues associated with the workers' health effects. The National Toxicology Program (NTP) will likely lead toxicology studies addressing chemical mixtures of concern, and EPA will collaborate on those studies.

NIEHS plans to enroll 55,000 workers and volunteers engaged in cleanup activities into a study population for an initial study duration of ten years, with the possibility of extending the follow-up. The primary objective of the study will investigate potential short- and long-term health effects associated with oil spill cleanup activities/exposure surrounding the DHW oil spill. The secondary objective is to create a resource for additional collaborative research focused on hypotheses or subgroups. Additional exploratory objectives include an investigation of biomarkers of potentially adverse biological effects in relation to oil spill cleanup activities/ exposure. The endpoints include respiratory, cardiovascular, hematologic, dermatologic, neurologic, cancer, reproductive, mental health, immunologic, hepatic, and renal effects. The study population would be broken into two groups of approximately 25,000 individuals (an active follow-up group and a passive follow-up group). The active cohort would have home visits, be administered health questionnaires, and have biospecimens collected. Nested within this cohort would be 5,000 individuals who would have additional biological samples collected, lung function testing, neurological testing, and mental screening. The passive cohort would not receive specimen collection or testing. Follow-up would include annual newspaper updates and passive surveillance of mortality and cancer registries.

NTP is also undertaking comprehensive analytical chemistry analyses of source oil and tar balls. The NTP is considering further toxicology studies in three main areas: (1) interactions between oil and dispersant constituents, (2) bioavailability and persistence of oil constituents or transformation products, and (3) relative hazards of various crude oils or crude oil fractions, specifically targeting poorly studied polyaromatic hydrocarbons (PAHs).

The EPA grantees will support oil spill research needs by addressing significant knowledge gaps. The EPA research grants program has identified priorities in three technical areas: (1) development of innovative mitigation technologies, (2) development of effective chemical dispersants, and (3) understanding ecosystem impacts. In addition, the grants program will support a Community Outreach effort that will empower Gulf Coast communities with an independent understanding of the underlying technical issues related to oil spill contamination and mitigation of impacted sites and encourage these communities to more fully participate in solving their environmental problems.

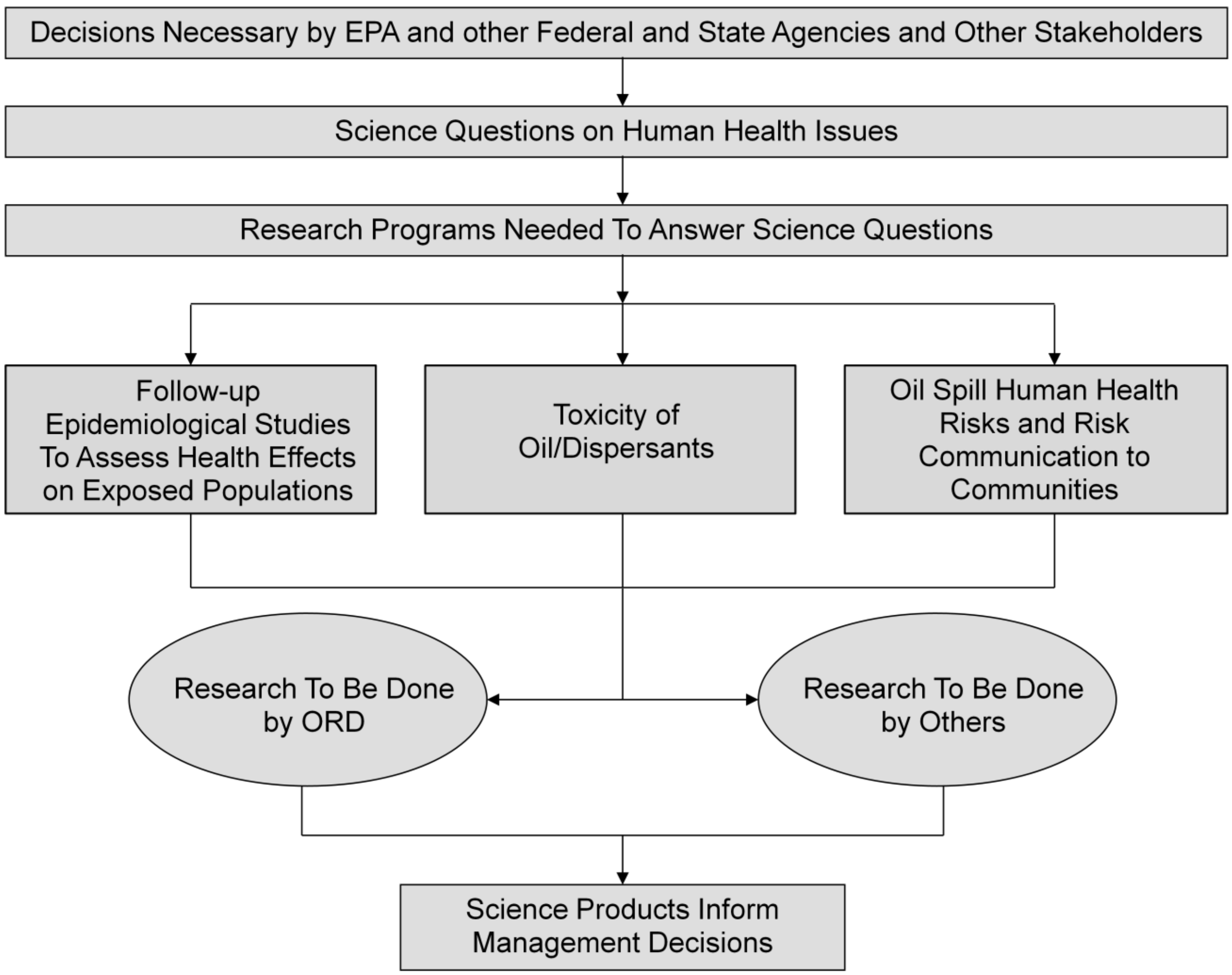

Figure 5-1 Human Health Effects Problem Formulation and Research Development Framework

b) Related Federal Research Activities

A NIEHS-led human health Interagency Gulf Oil Spill Task Force met regularly throughout the summer of 2010 to coordinate human health research activities associated with the DWH oil spill. The agencies represented include NIH, NIEHS, DHHS, CDC, EPA, NOAA, ATSDR, NIOSH, OSHA, Substance Abuse and Mental Health Services Administration (SAMHSA), and USGS. The meetings culminated with an interagency meeting hosted by NIH on August 19, 2010. At this meeting each agency described its current and planned research efforts. Those germane to human health research were:

1. **NIOSH**. BP asked NIOSH to conduct human health assessments of approximately 50,000 on-shore and off-shore workers during the summer. NIOSH is also considering undertaking animal toxicology studies of oil, dispersants, and combinations. This latter

activity meshes well with ORD’s capabilities and will be an area to pursue as a potential collaborative activity.

2. **CDC**. Using $3M in BP funds, the agency’s current efforts are focused on using the Behavioral Risk Factor Surveillance System to assess behavioral health issues of workers engaged in cleanup activities.
3. **SAMHSA**. The agency received $10M in BP funds to track behavioral health in the Gulf, with a specific focus on substance abuse.
4. **NIEHS/NTP**. The agency is exploring issuance of a Request for Applications (RFA) to fund university and community research in the Gulf on a wide range of health-related issues for their lead on the Gulf Worker Study: Gulf Long-Term Follow-Up Study for Oil Spill Clean-Up Workers and Volunteers (Interagency Meeting – Gulf Oil Spill Workers’ Study, 2010).

Many of these activities focus on health effects associated with the exposure of cleanup workers, most of whom are relatively healthy. Currently, the exposure of Gulf Coast residents to volatile compounds, dispersant/oil, or smoke plumes is unknown; however, this population includes subgroups much more susceptible to inhaled toxicants, such as pregnant women, the elderly, and those with cardiovascular or pulmonary disease. Therefore, the EPA has an opportunity to collaborate with (or fund) Gulf Coast universities engaged in long-term follow-up studies of residents for other reasons (e.g., progression of cardiovascular disease, incidence of cancer or birth defects, etc.). The registries can provide an assessment of participants’ health before, during, and after the spill. Other opportunities exist for EPA to engage in human health research associated with the DWH oil spill, such as using CDC’s BioSense syndromic surveillance network, which captures daily emergency room visits in hospitals throughout the Gulf Coast region (and the reason for the visit) (CDC, 2010).

Toxicology research to assess potential health effects of oil/dispersant suspensions and smoke plumes from burning unprocessed oil (which are very different in composition from those produced by burning refined oil) will be conducted by the NTP. This may provide an opportunity for EPA to collaborate if other agencies are also seeking to use newer molecular approaches to better understand the health effects associated with oil spill products (including secondary organic aerosols that are formed in the atmosphere and that travel long distances), oil/dispersant mixtures, and plumes from burning smoke.

c) Proposed Human Health Research Activities

1. Follow-up Epidemiological Studies To Assess Health Effects in Exposed Populations

Decision Context	Key Science Questions	Anticipated Outcome
Are there health effects associated with exposure of cleanup workers or gulf residents to the DWH oil spill?	Can any long-term health effects be identified in the cleanup workers who may have been exposed to very high concentrations of volatile compounds for short periods of time? Can any long-term health effects be identified in Gulf Coast residents who may have been exposed to oil, oil/dispersant emulsions, or emissions from the burning of oil?	NIEHS is leading a Gulf Coast Cohort study. Completion of this research will alert affected populations to potential health problems they may encounter in time for them to seek medical assistance, or to employ preventive measures prior to exposure in the future.
Do stressors related to the oil spill exacerbate health effects associated with exposure to oil spill related components?	What is the interaction between added stressors (e.g., heat, anxiety) and health effects caused by direct exposure to oil spill related components?	This research will help policy makers decide on community protective measures, such as evacuation of locations with potential exposures, in future oil spills.
Can the EPA provide a more accurate assessment of the exposure of affected populations to oil spill components?	Is the EPA providing the most up-to-date monitoring methods to measure potential exposure to oil spill related components?	This research will help attribute the causes of reported health effects in the affected communities, to identify individuals with high vulnerabilities, and to understand reported health problems where chemical exposures alone may appear insufficient to be a concern.

The NIEHS GuLF Cohort study will provide EPA an opportunity to utilize health effects data to evaluate and notify affected populations of the human health issues that may be associated with exposure to oil spills and chemicals used in oil spill remediation.

Research to assess health effects experienced by disaster response workers and USCG personnel

DWH response workers and USCG personnel were the populations with the greatest exposure to the oil spill. This population was exposed by inhalation and dermal absorption to potentially high levels of crude oil, VOCs from the oil, oil/dispersant emulsions, and emissions from burning the unprocessed oil. Although the toxicology of some of these chemicals has been studied individually in animal and acute human exposure studies, there is very little known about potential long-term effects from exposure to high levels of mixtures, particularly mixtures of oil and dispersants.

NIEHS will conduct long-term medical surveillance studies to determine the incidence of respiratory illnesses (e.g., asthma, chronic or recurrent cough or bronchitis, chronic obstructive pulmonary disease, lung cancer) in each of the disaster response workers. Researchers will obtain a detailed history from each subject regarding factors including, but not limited to type, duration, and intensity of exposure; use of personal protective equipment; and personal smoking history. The data will then be correlated with incident conditions, local ambient monitoring of $PM_{2.5}$, early biomarkers of exposure, and individual history of requiring medical attention for acute exposure symptoms during the spill event.

Research to assess health effects experienced by residents of communities

Direct exposures to oil spill pollutants

NIEHS will lead the studies of community health resulting from exposure to oil spill chemicals. This population contains more susceptible individuals such as children, the elderly, those with pulmonary and cardiovascular disease, those with autoimmune disease, and pregnant women. For example, previous epidemiologic and toxicologic studies of human exposures to petroleum-related VOCs have demonstrated adverse reproductive and neurobehavioral effects (Aquilera, et al., 2010), but other organ systems could also be impacted by non-volatile components (e.g., dispersants and smoke plume from burning oil). Temporal-spatial epidemiology (time-series and case-crossover studies) previously demonstrated the statistical power to examine relatively modest health impacts of low-level exposures across broad human populations.

Case-control studies from pre-existing cohorts or disease registries along the Gulf Coast are performed routinely for other reasons (e.g., studies of birth defects, progression of cardiopulmonary disease, and other health events using existing birth defect registries and clinical records) and will provide a baseline for the assessment of the health status of individuals in those cohorts. As these cohorts continue to be studied, it will be important to determine whether there are changes in long-term health status that can be attributed to the DWH oil spill.

Emergency rooms throughout the region capture daily admissions categorized by the International Classification of Disease, 9th Edition (ICD-9) code or chief complaint. These syndromic-based surveillance data can be analyzed in affected areas before, during, and after the spill to determine whether there was an increase in short-term health problems associated with the DWH oil spill.

Follow-up on the physical and cognitive development of children who may have been exposed to petroleum hydrocarbons* in utero *during the DWH oil spill

The developing organism, in particular the nervous system, is highly sensitive to exposure to toxic compounds. Some volatile hydrocarbons cause actions similar to those of alcohol, and fetal solvent effects have been reported that are similar to fetal alcohol spectrum disorders. Recent epidemiological studies linked reduced cranial size and impaired cognitive development with exposures to PAHs in children (Edwards et al., 2010). The cardiovascular or immunological systems of the fetus also may be sensitive to prenatal hydrocarbon exposures. Because of the potential susceptibilities, research will follow the general health and neurological/cognitive development of children born to mothers who were pregnant while also exposed to oil and/or oil vapors from the DWH oil spill.

Research to better define the exposure of affected populations to oil and its components or emissions

Environmental epidemiology studies are dependent on an accurate assessment of the exposure of a population to a pollutant. The DWH oil spill caused VOC emission and oil combustion emissions in the wake of the spill and the response to the spill. The emissions contributed to potential exposures to three major classes of air pollutants: direct petroleum-related chemicals, products of combustion of the spilled oil, and by-products of atmospheric chemical reactions. Although measurement methods for air pollutants where National Ambient Air Quality Standards exist are straightforward given the available Federal Reference Methods, the EPA found three areas of uncertainty associated with measuring potential exposures to air pollutants associated with the DWH oil spill:

- Measurement of specific volatile air toxics (e.g., low levels of benzene)
- Identification of odor-causing chemicals in coastal communities
- Quantification of petroleum-based secondary organic aerosols

EPA's TO-12, TO-14, and TO-15 Methods (method determination of toxic organic compounds in ambient air) would be reviewed and adapted specifically for large oil spills. Based on an assessment of the gaps in measurements for air toxics along the coast, research will be conducted to improve the methods, thus filling the gaps in current method capability. In addition to air toxics, EPA received numerous odor complaints during the DWH response that were possibly associated with the spill, and odor-causing pollutants associated with oil were observed on the shore in the Gulf Coast region at low levels.

2. Toxicology of Oil/Dispersants

The NTP is considering further toxicology studies in three main areas: (1) Federal interagency studies of interactions between oil and dispersant constituents, (2) bioavailability and persistence of oil constituents or transformation products, and (3) relative hazards of various crude oils or crude oil fractions, specifically targeting poorly studied PAHs.

a. Exposure and Sensitive Populations

Decision Context	Key Science Questions	Anticipated Outcome
What are the toxicological effects of oil and dispersants, especially with regard to human health?	What model toxicology systems should be used to evaluate oil and dispersants?	Identification of the key health effects of these mixtures in model systems will provide information on what health effects such mixtures might cause in humans.
	What are the short-term and long-term health effects of dispersants and dispersant-oil?	Characterizing these effects in model systems will provide information on potential acute or chronic health effects in humans.

Research to evaluate humans with various levels of potential exposure to spilled oil or oil-contaminated media, including dispersant or dispersant-oil mixtures

NTP will likely lead research on oil, dispersants, oil-dispersant mixtures, and combustion emissions from oil burning. Research will be performed for a wide range of health endpoints, including dermal sensitivity, neurotoxicity, genetic toxicity, whole-animal toxicity, developmental toxicity, and genomic and high-throughput assay endpoints involving receptor binding and pathway disruption. Research efforts will build on what is in the existing literature, which derives largely from studies prompted by the Exxon Valdez spill as well as oil burning in Kuwait (Brain et al., 1998; Kelsey et al, 1994). Despite modest literature on these two events, there is still a large amount of systematic research called for to gain a better understanding of the potential health effects from these types of exposures. A key area of research will assess the *in vitro* studies on the best methods for extracting organics from the samples for testing. Few systematic studies on this important first step have been conducted. Research will encourage utilizing the most validated and standard assays, as well as emerging assays using the latest molecular endpoints, even though these may not yet be validated or fully understood. Such a combined effort will provide a linkage between older, established methodologies and newer ones. As a result, new methods can be used with confidence on real-world environmental samples associated with oil spills.

Research to determine the most sensitive and relevant biomarkers measured to assess exposure and effects from oil and dispersants

Research on analytical methods will be conducted to assess PAHs and volatiles in oil, as well as selected components of dispersants in urine and blood and possibly exhaled breath. Sensitive methods exist for many of the types of compounds present in oil; however, further research will assess the use of these assays and develop such assays further to ensure the value of their use in people exposed to oil and/or dispersants.

Research will evaluate biomarkers of effect, such as genotoxic biomarkers, including the comet assay and micronucleus assays for DNA damage, and urinary mutagenicity as a measure of systemic exposure to genotoxins. Sstandard methods exist for these endpoints; however, they have not been used in subjects exposed to oil spills and/or dispersants. Further research will be conducted to understand whether such assays are useful for these types of environmental exposures. Genomic endpoints, such as alterations in the expression of genes or levels of proteins, could be applied to oil-exposed individuals if such endpoints were assessed and developed sufficiently for this purpose. Thus, research into the application and development of “omic” endpoints will be encouraged.

b. Acute Respiratory and Dermal Health Effects

Decision Context	Key Science Questions	Anticipated Outcome
Does burning of unprocessed oil in open water cause acute cardiovascular effects in cleanup workers or nearby residents?	What are the cardiovascular effects associated with exposure to smoke plumes from burning oil?	Completion of this NIEHS-led research will allow a comparison of the toxicity of PM derived from burning oil with other forms of combustion-related PM whose cardiovascular effects are well understood.
Does dermal contact of oil or volatile emissions from oil cause skin problems in cleanup workers or nearby residents?	Does dermal contact with oil cause irritant contact dermatitis, allergic sensitization or delayed-type hypersensitivity?	Completion of this research will determine whether cleanup workers and residents need to wear protective clothing to minimize dermal contact with oil or oil emissions.

Considerable research has defined health effects (primarily cardiovascular) caused by PM emitted during combustion of fossil fuels. The World Health Organization estimates that annually more than 800,000 deaths each year are attributed to PM; cardiovascular events are the primary cause of this mortality. However, the chemical makeup of many of those fuels is likely very different from emissions associated with the burning of unprocessed oil. Emissions from the Kuwaiti oil fires of 1991 did not appear to cause significant respiratory effects in the populations studied (Cherry et al., 1991; Kelsey et al., 1994), but those studies did not examine cardiovascular effects.

Research to determine whether exposure to PM emitted from burning unprocessed oil causes adverse cardiovascular effects

Toxicological studies will compare the potency of emissions from burning unprocessed oil with emissions from other sources (e.g., diesel engines, power plants, refineries, automobiles) for which considerable risk assessment information is available.

If warranted, human clinical studies will define the cardiovascular changes induced by exposure to burning unprocessed oil. Animal and *in vitro* studies will characterize and compare the underlying mechanisms by which PM from burning unprocessed oil causes cardiovascular effects with the mechanisms by which other sources of PM cause such effects. Studies will determine whether some subpopulations potentially exposed to oil-related PM are especially susceptible and may need to be protected (e.g., wearing appropriate face masks or being evacuated) in the event of future oil spills.

Research to evaluate the risks of dermal exposure to dispersant/oil mixtures

Some oil products are known to affect skin. Animal studies have suggested that fuels can cause or alter irritant contact dermatitis, allergic sensitization, and delayed-type hypersensitivity (McDougal and Rogers, 2004). However, few studies have examined dermal effects of unprocessed oil at the concentrations present in the Gulf Coast region. Additionally, it is unknown whether the oil/dispersant mixture might alter penetration of oil into the skin. Thus, research will assess the dermal effects of dispersant/oil mixed under conditions that occurred in the Gulf Coast region. The goal of the research is to understand whether a hazard exists for the general public, who may be exposed through swimming or on the beaches, or to cleanup workers who may be exposed though occupational activities. In addition to animal models, several well validated *in vitro* models exist that can effectively evaluate risk. For example, reconstructed human skin models (e.g., Episkin) can be used to test for genotoxicity. Three-dimensional skin models can be used to test for dermal irritation or skin corrosion, and human keratinocytes can be used to test for sensitization.

c. Acute Neurological Health Effects

Decision Context	Key Science Questions	Anticipated Outcome
Does exposure to oil spill related constituents cause acute neurological health effects?	Are there neurological effects in cleanup workers or nearby residents that can be related to exposure to organic vapors associated with the DWH oil spill?	Completion of this research will determine whether acute health effects warrant workers wearing cumbersome but effective masks and protective clothing.
	Are neurological effects associated with exposure to mixtures of hydrocarbon vapors worse than the sum of the effects of exposure to individual vapors?	Completion of this research will determine whether risk assessors can assume that exposure to mixtures of vapors results in an additive or synergistic effect.
	What is the dose-response function for acute exposures to hydrocarbon vapors?	Completion of this research will provide information about health effects caused by various levels of vapors and lengths of exposure, thus enabling better protection of exposed workers and residents.

Research to evaluate the risks of cumulative petroleum hydrocarbon vapors instead of assessing the risks on a single chemical-by-chemical basis

The current approach to assessing the risks of exposure to the DWH oil vapors is based on single chemicals. The only VOCs mentioned on the EPA Web Site (USEPA, 2010f) are benzene, toluene, xylene, and ethylbenzene. Exposure to the vapor-phase components of an oil spill, however, is undoubtedly a simultaneous exposure to hundreds of organic volatile hydrocarbon compounds, of which BTEX reflect only a small proportion of the total volume. The acute effects of these VOCs, including sensory irritation, acute neurological impairment, and feelings of general illness (e.g., headache, nausea) are likely similar among many of these hydrocarbons, so that the substances act together in a cumulative toxic fashion. Therefore, estimating the risks using only a few of the many compounds present underestimates the health risks of exposure to the mixture. The protection of public health in such situations requires a cumulative exposure approach to the risk assessments. If funds are available, research will determine the best approaches to estimating the cumulative risks of exposures to total hydrocarbon vapors.

Research to define the dose-time-response functions for acute exposures to volatile petroleum hydrocarbons

Among the petroleum hydrocarbon VOCs, the cancer concern is relevant primarily for benzene. There are also multiple non-cancer health outcomes of concern following exposure to petroleum hydrocarbons. The non-benzene VOCs include toluene, xylene, ethylbenzene, and many other volatile petroleum hydrocarbons. Acute exposure to these compounds causes neurological impairments, irritation of sensory and respiratory tissues, and acute illness symptoms (headache, nausea etc.). The acute effects are caused more as a function of the momentary peak air concentrations than the mean annual air concentrations. The relationships between acute air concentrations, momentary concentrations of hydrocarbons in the brain, and impaired neurological function have been demonstrated for several volatile hydrocarbons, including toluene, trichloroethylene, and perchloroethylene. Acute irritation of respiratory and ocular tissues has been reported among workers in the Gulf Coast region, and is likely predicted better by the acute peak air concentrations than the mean annual averages. Research will better define the response surface for acute exposure concentrations and durations in producing these multiple acute health effects for exposures to total hydrocarbon vapors. Research will also develop better acute exposure risk values, especially for non-cancer outcomes, to apply them in risk assessments of this sort.

Research to further develop physiologically-based pharmacokinetic (PBPK) models and link them to adverse outcomes for volatile hydrocarbon mixtures

EPA is currently developing a PBPK model for the complex mixture of gasoline vapors, which contains a set of volatile hydrocarbons similar to that vaporized from the DWH oil spill. EPA's previous research indicated that the acute neurological impairments of volatile hydrocarbons can be predicted by their momentary molar concentrations in brain tissue. It is assumed that multiple hydrocarbons act additively in the brain. Therefore, the relative toxicity of a complex mixture of hydrocarbon vapors could be estimated as the additive molar hydrocarbon concentrations in the brain. The relative molar concentration of vapor constituents could be predicted using PBPK models that employ several parameters measured or estimated for each constituent such as vapor pressure, partition coefficients, and rates of metabolism. Approaches are available to estimate some of these parameters, which may not be available for some compounds, such as quantitative structure-activity response models. Research will further develop and validate such approaches and translate them into formats that are practically applicable for risk assessments.

3. Oil Spill Human Health Risks and Risk Communication to Communities

Decision Context	Key Science Questions	Anticipated Outcome
What is the risk associated with exposure of humans to an oil spill?	Can oil spill related data be used to develop a formal risk assessment document that defines the risk to cleanup workers and nearby residents?	Development of a human risk assessment based on data obtained from research described in this strategy would aid in characterizing the risk associated with oil spills.
How will ORD communicate that risk to affected populations? What are better tools to communicate with communities?	How can communication of health issues related to oil spills to communities be improved?	Better capacity building to effectively partner with communities.

Research to address hazard identification, dose-response, and exposure assessment within the risk assessment paradigm for evaluating human health risks associated with oil spills

Research will evaluate data on oil, dispersants, and related oil mixtures. The composite assessment will aid in characterizing the risk associated with oil spills. A strategy will then will be developed to effectively communicate the associated risk to risk managers, the public, and interested stakeholders.

A human health risk assessment dossier is a valuable resource for risk assessors, risk managers, decision-makers, stakeholders, and the public. It provides a compilation of the available literature as well as an evaluation of the human health effects associated with an exposure of interest. The development of a human health risk assessment on oil, dispersants, and related oil mixtures will serve to inform and communicate to interested parties about the associated risks of these compounds. The composite assessment will include the following components to adequately characterize the associated risk: hazard identification, dose-response, and exposure assessment.

Research will include a compilation and evaluation of the available body of literature, along with data from the proposed *in vivo* and *in vitro* research, on the human health effects of oil, dispersants, and related compounds to better identify the human health hazards associated with oral, inhalation, and dermal routes of exposure. The inclusion of mixtures research, PBPK modeling, and mode-of-action of the compounds will be valuable in the hazard identification component of the overall assessment. In addition to the hazard identification, a dose-response assessment will be used to evaluate the relationship between the level of exposure to spilled oil, dispersants, and related compounds and the observed human health effects. Susceptibility issues relating to age and genetic predisposition will be addressed pending the availability of such information. The research on the potential exposure to spilled oil, dispersants, and related oil mixtures, as well as biomarker research to identify exposure to the aforementioned chemicals, will serve as the basis for the exposure assessment component within the risk assessment/risk management framework.

Research to improve risk communication for oil spills and build community partnership capacity to address issues

The EPA research grants program will support a community outreach effort. This endeavor will provide Gulf Coast communities with an independent understanding of the underlying technical issues related to oil spill contamination and mitigation of impacted sites. It will also promote community engagement in indentifying environmental issues and presenting solutions to the problems.

In an emergency response, communication to the impacted community is an important issue. EPA will work with OEM and EPA Regions to develop methods to improve risk communication. In the short-term, measures to improve information sharing among Federal agencies will ensure that consistent information regarding human health risks is disseminated to the public. For long-term consideration or in preparation in the event of a similar oil spill disaster, a strategic plan will be developed. This plan will outline how EPA will communicate scientific data and concerns of the public with other Federal agencies and interested parties. The risk communication plan will establish multidisciplinary teams responsible for community outreach activities in the form of community meetings, telephone or Web-based hotlines, and printed or electronic communication materials.

Working with EPA Regions (e.g., Community Action for a Renewed Environment [CARE] Coordinators), EPA will conduct research to improve methods to collaborate with affected communities. EPA will work to improve exposure assessment tools and provide additional scientific information to community groups. It is anticipated that cooperative agreements with academic institutions will allow a variety of expertise to be applied to building community capacity.

d) Progression of Human Health Research Activities

The proposed research strategy illustrates the problem formulation developed for human health impacts that identify the specific science questions and subsequent research activities that will ultimately inform management decisions. The research on human health includes follow-up studies to assess health effects on exposed populations, acute health effects, toxicity of oil/dispersants, and assessing risks associated with exposure to oil/dispersants. Figure 5-2 illustrates the progression of human health impacts research from FY 2011 through FY 2015.

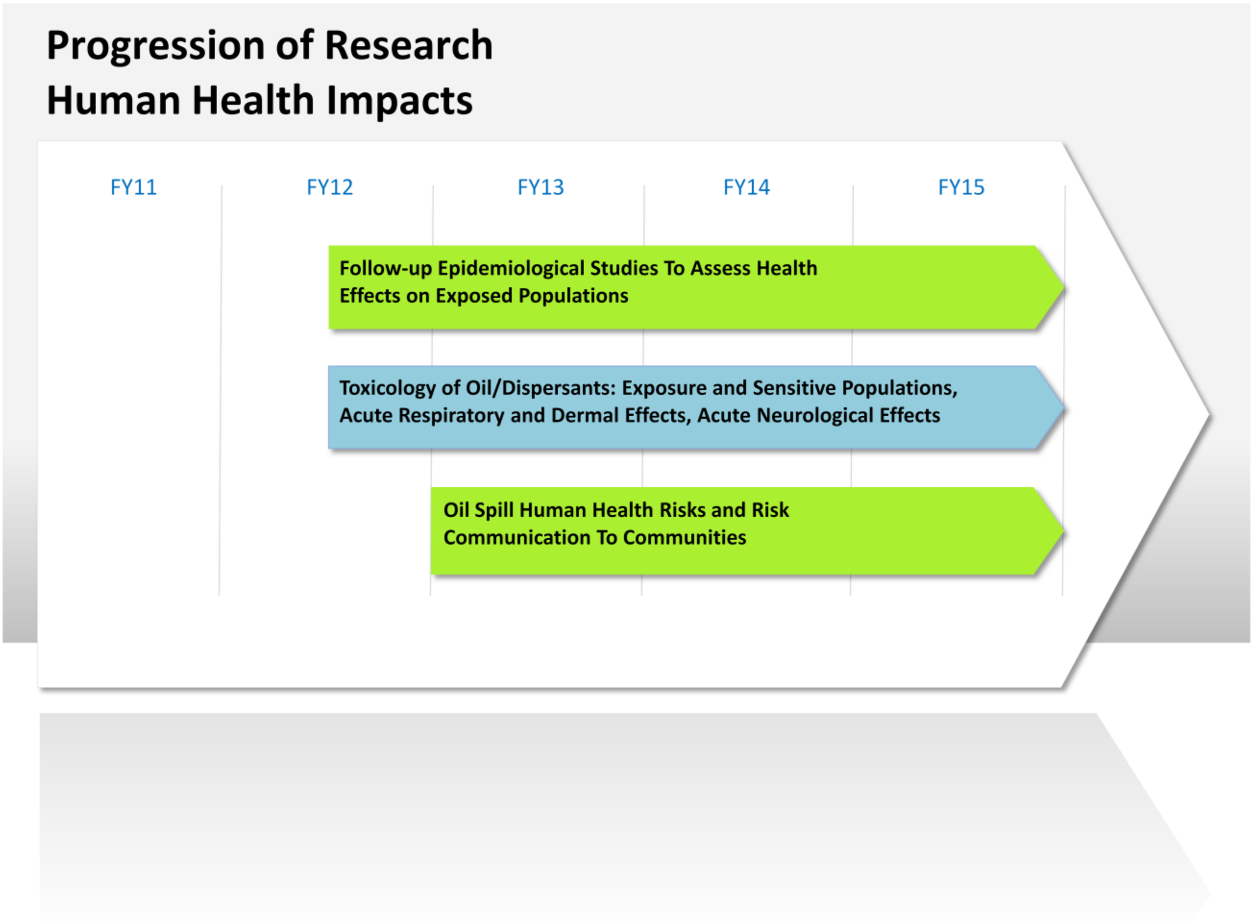

Figure 5-2 Progression of Human Health Research

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

<table>
<tr><th>Agency</th><th>Historic Research Area</th><th>Deepwater Horizon/Gulf of Mexico Research Area</th></tr>
<tr><td colspan="3">U.S. Environmental Protection Agency</td></tr>
<tr><td><u>Objectives</u>:
1) Providing environmental managers with the tools, models, and methods they need to better understand the fate, exposure, and effects of oil spills on ecosystems and to clean them up effectively.
2) Improved scientific understanding of the factors affecting dispersant products used to mitigate the effects of oil spills on open waters and improved understanding of the characteristics of flow to ecosystems</td><td>- Scientists developed a new Baffled Flask Test (BFT) for testing dispersant effectiveness and representing more accurately the over-and-under mixing energy of breaking waves at sea.
- Scientists developed guidelines for the bioremediation of marine shorelines, freshwater wetlands, and salt marshes for use by spill responders.
- Researchers are developing a new approach to treat vegetable oil spills. http://www.epa.gov/nrmrl/lrpcd/rr/projects/56298.htm
- Scientists developed the EPA Research Object-Oriented Oil Spill (ERO3S) model for use by on-scene coordinators and oil spill response planners. The objective of this model is to develop a multi-component mass balance-based model for simulating transport of spilled oils with and without dispersant treatments.
- A wave tank at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, has been used to improve international scientific understanding and responses to oil spills at sea. EPA scientists are involved in this international effort with DFO.
- Lock Lake in East Patchogue, New York, is a tidal marsh where EPA scientists study the waterway’s natural processes, such as water flow, to understand the impacts of oil spills on tidal marshes, provide data to evaluate subsurface and surface water interactions, determine transport characteristics of spilled and dispersed oil, and aid in the development of simulation models to reproduce and predict transport of oil spills.</td><td>- Supporting and advising USCG efforts to clean the shoreline and closely monitor the effects of dispersants in the subsurface
- Directing management of recovered oil, contaminated materials, and wastes in cleanup operations
- Monitoring air quality throughout the Gulf region
- Assisting USCG in approving waste management plans for recovered oil and waste generated from the spill
- Predicting air quality impacts resulting from the oil spill
- Research on dispersants
- Collecting shoreline samples for chemicals and dispersants</td></tr>
</table>

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
	- NCP Product Schedule Support. Research was key to the development of a list of chemicals and other products for use in oil spill cleanup. The list, developed under Subpart J (40 CFR Part 300.910) of the NCP, includes current dispersants, surface washing agents, bioremediation agents, and miscellaneous oil spill control agents. http://www.epa.gov/emergencies/content/ncp/index.htm	
National Oceanic and Atmospheric Administration (NOAA)		
Objective: *Develop the information and tools to make reliable decisions in preparedness, response, damage assessment, and restoration. Reduce human risk and environmental and economic consequences resulting from natural or human-induced emergencies.* **Represents research implemented through the CRRC*	- Investigate the use of alternative response technologies (e.g., *in situ* burning or the use of dispersants) - Develop a robust database for managing shoreline assessment information for large and complex spills - Examine the issues of measuring and predicting the effects of oil and dispersed oil components on ecological endpoints* - Identify the societal, economic, and cultural consequences of spills and associated response activities on affected communities - Develop an integrated and effective research strategy to improve modeling, detection, and monitoring capabilities for submerged oil (partnered with USCG)* - Use research results from Oil-in-Ice to improve risk assessment and response methods for the Arctic environment.	- Conducting and coordinating subsurface sampling for presence of oil - Collecting baseline data on water quality, seafood quality, and the status of natural resources - Utilizing vessels for water sampling near Deepwater Horizon well-head and coastal zone - Work with DOI in coordinating expedition to Gulf to locate, map, and investigate deep water habitats - In Spring 2011, launch of Gulf of Mexico Disaster Response Center - Predict flow of surface oil using high frequency radar data - Collecting air quality data and modeling local and regional air quality impacts. - Analyzing subsurface samples to gain understanding of extent of spill

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
U.S. Coast Guard (Department of Homeland Security [DHS])		
Objective: *To enhance acquisition and mission execution by providing applied scientific research, development, testing, and evaluation of new technologies for the maritime environment. Coast Guard responds to releases and substantial threats of releases of oil in the coastal zone, the Great Lakes, and inland river ports.*	- Utilizes OSLTF to (1) provide for Federal OSC to respond to discharges and for Federal trustees to initiate NRDA and (2) administer the provisions of OPA-90 for support research and development. - The OIS is based on a multi-method approach to “fingerprinting” oils.	- On June 4, 2010, the Coast Guard issued a Broad Agency Announcement to establish an IATAP. The IATAP was designed to establish a well defined, documented, systematic, and fair government-managed process to solicit, screen, and evaluate vendor/other government agencies/academia-suggested technologies in support of ongoing response activities.
National Institute of Standards and Technology (NIST)		
Objective: *To support regulatory and industry requirements for reference materials and standards.*	- To produce and maintain a large inventory of fossil fuel Standard Reference Materials certified for sulfur and other trace elements (including mercury and chlorine). - Continually adapt to meet the rapidly changing needs of the energy sector.	
Office of Fossil Energy (DOE)		
Objective: *To advance the national economic and energy security of the United States by ensuring that we can continue to rely on clean, affordable energy from our traditional fuel resources.*	- The National Energy Technology Laboratory conducts research on new energy technologies and methodologies to promote efficient and environmentally sound approaches for oil extraction and use of our nation’s fossil fuels. - The Rocky Mountain Oilfield Testing Center will test capabilities for oil and gas production, drilling, renewable energy, flow assurance, bioremediation, wetlands creation, well completions, and geology and petrophysics.	- Providing information on the configuration of the well, the blowout preventer, the lower marine reservoir package, and the riser configuration as best known after the April 20 fire on the Deepwater Horizon, including the depths and sizes of the different casings installed during the well’s construction - Summarizing key events, including operations such as the kill attempt, the

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
		cutting of the riser, and recovery of hydrocarbons at the surface - Recording the short- and medium-term containment and collection efforts that have been implemented as well as data from surface collection efforts to date - Collecting data on surface oil collection: combined total amount of oil and gas recovered daily from the Top Hat and Choke Line oil recovery, oil and gas recovery from the Riser Insertion Tube (while connected), oil and gas flow data from the Top Hat and Choke Line - Compiling data on the Blow Out Preventer, Lower Marine Riser Package, and associated piping, and pressure data within the Blow Out Preventer - Gathering information on the top kill process (while being conducted)
Bureau of Ocean Energy Management, Regulation and Enforcement (DOI)		
Objective: *Activities of BOEMRE Oil Spill Response Research program comply with the research and development provisions of Title VII of the Oil Pollution Act of 1990.*	- BOEMRE has funded more than 120 projects directly related to oil spill research including (1) oil behavior in water, (2) chemical treating agents and remote sensing, (3) spill response in arctic environments, (4) mechanical containment options, and (5) *in-situ* burning. - BOEMRE manages the Ohmsett facility, a 600-foot-long test tank, which has been integral to many of these	

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
	projects, and remains an important tool for BOEMRE, academia, and the oil spill response industry.	
Pipeline and Hazardous Minerals Safety Administration (PHMSA) (Department of Transportation [DOT])		
Objective: *To decrease the likelihood of pipeline spills, diminish the environmental consequences of spills, and ensure that the responses to spills are swift and well-planned.*	- Comprehensive program dedicated to protecting the environment from major oil spills through risk assessment and regulatory compliance (Federal and State partnership).	
U.S. Fish and Wildlife Service (DOI)		
Objective: *To emphasize early (contingency) planning and cooperation at the local, regional, and national levels in an effort to minimize the injury to fish, wildlife, and sensitive environments from oil spills.*	No specific projects located.	- Contributing in the coordination of NRDA activities under OPA-90 to identify, implement, and further develop short-term restoration projects and long-range plans - Participate in technical workgroups for NRDA activities
Maritime Administration (MARAD) (DOT)		
Objective: *Maritime Administration plays a key role in asserting the need for consistent, uniform international laws and policies.*	No specific projects located.	No specific projects located.
U.S. Army Corps of Engineers (Department of Defense [DoD])		
Objective: *To establish emergency permitting procedures for activities involving structures within U.S. waters including booms and objects pertaining to cleanup efforts.*	No specific projects located.	No specific projects located.
U.S. Navy (DoD)		
Objective: *Focus all oil spill containment technologies and glider operations.*	No specific projects located.	No specific projects located.

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
National Aeronautics and Space Administration (NASA)		
Objective: *To pioneer scientific discovery and utilize space-based sensors for oil detection in surface waters.*	No specific projects located.	No specific projects located.
Federal Emergency Management Agency (FEMA)		
Objective: *To build, sustain, and improve our capability to prepare for, protect against, respond to, recover from, and mitigate all hazards.*	No specific projects located.	No specific projects located.
Interagency Coordinating Committee on Oil Pollution Research (ICCOPR)		
Objectives: *(1) To prepare a comprehensive, coordinated Federal oil pollution research and development (plan; and (2) to promote cooperation with industry, universities, research institutions, State governments, and other nations through information sharing, coordinated planning, and joint funding of projects. The Interagency Committee was commissioned with 13 members and is chaired by the Coast Guard. Link to Report:* *http://www.regulations.gov/search/Regs/home.html#documentDetail?R=0900006480aed149*	Members: EPA; Department of Commerce (NOAA, NIST); DOE; DOI (BOEMRE, FWS); DOT (MARAD, PHMSA); DoD (USACE, FEMA); NASA; DHS (USCG, FEMA, U.S. Fire Administration)	No specific projects located.
ICCOPR projects completed through 2009 include research covering 13 areas: - Alternative Technologies - Command, Control, and Communications	Collaborators: EPA, NOAA, BOEMRE, USCG, CRRC, State level groups, DFO-Canada	No specific projects located.

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
- Fate and Behavior Modeling Analysis - Hazardous Substance Response - Natural Resources Injury Assessment and Restoration - Oil Toxicity and Effect - Remote Sensing and Aerial Observation - Human Dimensions - Submerged, Sunken, and Heavy Oils - Shoreline Assessment - Oil-in-Ice and Cold Weather Response - Chemical Treating Agents and Dispersants - *In-Situ* Burning		
Gulf Coast Ecosystem Restoration Task Force		
<u>Objectives</u>*:* *(1)Support the Natural Resource Damage Assessment (NRDA) process and coordinate non-NRDA ecosystem funds and projects.* *(2) Restoration of the Gulf Coast and its communities following the five principles defined by the Task Force*.	Not applicable	- Members: DOC, DOI, DOT, EPA, USACE, U.S. Department of Agriculture, Department of Justice, Council on Environmental Quality, Office of Science Technology and Policy, and the Domestic Policy Council and a representative from each Gulf State - DHHS, DHS, DOJ, the Department of Labor, and the Small Business Administration will serve in an advisory role to offer guidance on issue-specific topics - Ecosystem restoration including the health and well-being of the following:

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
		- Coastal wetland and barrier shoreline habitats - Fisheries - Coastal communities - Sustainable storm buffers - Inland habitats, watersheds, and off-shore waters
National Response Team		
Objective: *The NCP is the Federal government's blueprint for responding to both oil spills and hazardous substance releases. The NCP established the National Response Team, composed of 15 Federal agencies. EPA serves as chair of the NRT and USCG serves as vice-chair.*	No specific projects located.	- Assisting responders by formulating policies and providing information, technical advice, and access to resources and equipment for preparedness and response to oil spills and hazardous substance releases.
Dredging Program Technical Workshop: EPA and USACE		

Objective: *To address some of the fundamental questions to develop a short-term and long-term process for dredged material evaluations. To accomplish this goal, specific questions listed below will be addressed. It is expected these discussions will enable the workgroup to develop a coordinated, scientifically based process for (1) immediate response to support the dredging program in light of the dynamic nature of the oil contamination and (2) long-term assessment of oil contamination using the best available approaches.*	Not applicable	- Key research areas will cover:
		  - Oil contamination
		  - Dispersants
		  - Sampling
		  - Analytical chemistry
		  - Screening values
		  - Bioassays
		  - Management of oil contaminated sediments

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
NIEHS: Interagency Workgroup		
Objective: *NIEHS is taking the lead on forming a Gulf Oil Spill Response Interagency Workgroup to Coordinate Human Health and Research. The workgroup will coordinate public health monitoring for human health effects related to exposures associated with the Gulf oil spill; plan, coordinate, and facilitate short-term and longer range efforts for human health response monitoring and research; and identify and engage other stakeholders to plan or to conduct human health monitoring.*	Not applicable	- The six subworkgroups will cover the major themes: - Stakeholders - Health and Toxicology Information - Survey/Roster/Questionnaire Tools - Human Health Problems Surveillance - Human Health Biomedical Monitoring - Research
Department of the Interior: Strategic Sciences Working Group (SSWG)		
Objective: *DOI established the SSWG to assess how the Deepwater Horizon oil soil may affect the ecology, economy, and people of the Gulf of Mexico. It included scientists from diverse disciplines and Federal, academic, and nongovernmental organizations. The SSWG was not to conduct a scientific investigation, but to provide rapid scientific assessment of the potential consequences of the spill that could provide usable knowledge to decision-makers.*	Not applicable	- Activities include: - Constructing science-based scenarios to identify alternative futures - Identifying key variables through adapting and applying a specific, coupled natural-human system model - Developing a conceptual framework adapted from the natural hazards literature - Activities include: - Independence from standard response structure (e.g., the Incident Command System and

Table A-1. List of Ongoing and Anticipated Federal Oil Spill Research Activities

Agency	Historic Research Area	Deepwater Horizon/Gulf of Mexico Research Area
		Natural Resource Damage Assessment); - Collaborative engagement of Federal and nonfederal scientists; - Rapid scenario-building within a disciplinary framework; - Assignment of scientific uncertainties; and - Potential application to mid- and long-term recovery.

Appendix B

Table B-1 Deepwater Horizon Oil Spill Related Research Ongoing at Academic Institutions

From Oil Spill Activities Clearinghouse (http://igulf.noaa.gov, dated 7/12/2010) (NOAA, 2010b)			
*Information summarized from original submissions. Research is either completed, ongoing, or proposed. Designation of "unknown" is from original table. Submissions are reorganized by "Primary Environmental Theme" except **			
Organization	**Objective**	**Research Area**	**Primary Environmental Theme**
*Gulf of Mexico Alliance (Gulf of Mexico Alliance, 2010)	Partnership of the states of Alabama, Florida, Louisiana, Mississippi, and Texas, with the goal of significantly increasing regional collaboration to enhance the ecological and economic health of the Gulf of Mexico.	Each State is implementing an emergency response plan. Ongoing activities of the Alliance will support future mitigation actions related to water quality and the habitats impacted by the DWH incident.	Response/ Mitigation
Dauphin Island Sea Lab	Oil Spill Effects on Manatee Distribution in Alabama and Mississippi. Partially funded through Alabama Division of Wildlife and Freshwater Fisheries. Partially funded.	Current baseline data on distribution, movement patterns, and population structure of manatees relative to oil movement is being collected.	Coastal and Nearshore Habitats
Dauphin Island Sea Lab	To conduct aerial surveys for manatees for the duration of the spill. Funding NRDA. Partially funded.	In collaboration with Sea to Shore Alliance in Florida, weekly aerial surveys are being conducted for emergency response.	Coastal and Nearshore Habitats
University of North Carolina Wilmington Center for Marine Science	Assess the potential influence of the oil spill on the effects of inhaled Florida red tide brevetoxins on Sarasota beaches. Funding DHHS, NIH, NIEHS, CDC, Department of Health, and Florida.	This study will piggyback on a long-term, ongoing study by multiple disciplines and collaborators on the effects of inhaled Florida red tide brevetoxins on Sarasota beaches.	Coastal and Nearshore Habitats
USM/GCRL	Study of Mississippi coast sport fish. Funding by Louisiana Sea Grant.	Gill net sampling will be used to monitor the status of coastal sport fish.	Coastal and Nearshore Habitats
Nicholls State University	Reserves building for survival and replenishment of coastal plant. No funding.	Collecting, propagating, and establishing germplasm reserves of coastal plants from multiple sites. Emphasis on smooth cordgrass.	Coastal and Nearshore Habitats
Louisiana State University	Determine the effects of dispersants on juvenile blue crabs. Funded by Louisiana Sea Grants.	Standard static LC_{50} 96-hr trials with Corexit® 9500 will be funded as well as 24- and 48-hr dosing experiments	Dispersants
University of Southern Mississippi	Assess the impact of crude oil and dispersants on growth, survival, and behavior of blue crab zoeae and megalopae. No funding.	Monitoring and toxicological experiments at several sites are being used to estimate lethal tolerance and chronic sub-lethal exposure and effects of zoeae and megalopae to crude oil and dispersants.	Ecosystem and community structure
Dauphin Island Sea Lab	Monitor oiling of colonial nesting colonies. No funding.	Colonial nesting colonies from Cat Island, Alabama, Gaillard Island, Goat Island, Robinson Island, Pelican Island, and Dauphin Island for any oiled birds, clutch, and hatching alterations and population declines	Ecosystem health and indicators
University of New Orleans	Assess long-term oil spill impacts on juvenile fishes, crabs, and shrimp by comparison to existing baseline data. Funding by Louisiana Sea Grant.	Post oil spill seine, trawl, and gillnet data are being compared against existing baseline data to assess impacts on local juvenile fishes, crabs, and shrimp tagged lemon sharks to assess long-term impacts.	Ecosystem health and indicators
Auburn University	Assess the seasonal effects of the spill on oyster biological responses. No funding.	Multiple sites are being monitored to compare the effect of the spill on oyster survival, growth, contamination, and	Ecosystem health and indicators

		other biological responses to provide quantitative, statistically meaningful assessment of differences among sites.	
Harte Research Institute	Establishing changes in offshore macrofauna and meiofauna. No funding.	Comparing current conditions of benthos in Gulf of Mexico sediments from 25-3,000 m with baseline conditions assessed during the last decade.	Ecosystem health and indicators
Louisiana State University	Assess the pathways and rates at which hydrocarbons from the spill are incorporated into the local marine food web. Funding by Louisiana Sea Grant.	Examining three primary sensitive consumers to trace secondary impacts of organic compounds moving through trophic levels of the coastal ecosystem.	Ecosystem health and indicators
Tulane University	Estimate the effects of the oil spill on the recruitment of the blue crab into Gulf of Mexico estuaries. Funding by Louisiana Sea Grant.	Using particle-tracking model to simulate blue crab larval dispersal in the Gulf of Mexico with and without the oil spill kill zone.	Ecosystem health and indicators
Louisiana State University	Coastal march stations are being assessed for baseline oil, microbial, meiofaunal, and vegetative parameters. No funding.	18 stations are being sampled over time for these parameters.	Ecosystem health and indicators
University of Nevada-Reno	Assess effects of oil and particulate organic carbon fallout on the deep sea floor. No funding.	Effects of oil on meiofauna community structure and function will be focused on comparison to an existing dataset for harpacticoid copepod species diversity.	Ecosystem health and indicators
Dauphin Island Sea Lab	Oil spill effects on manatee habitat and food supply. Partially funded through Alabama Division of Wildlife and Freshwater Fisheries.	Conditions at known key manatee habitat sites in Alabama, including sediment, water column organic composition, and isotope ratios and species types.	Ecosystem health and indicators
Dauphin Island Sea Lab	Determine how nearshore organic matter and food species are affected by oil spill related contaminants. Funding from Shelby Center for Fisheries Management.	Current and future data on water column, sediment, and species composition along a salinity gradient from the Mobile-Tenshaw Delta will be compared with data from the past two years. Data will include C and N composition, stable isotope ratios, and species types.	Ecosystem health and indicators
Dauphin Island Sea Lab	Oil spill effects on oyster physiology in Alabama waters. No current funding.	Studying long-term cumulative and sublethal effects of direct oil related contamination and indirect effects associated with hypoxia on oyster growth and survival.	Ecosystem health and indicators
Louisiana Sea Grant Program	To monitor the effects of the oil spill on water quality. No funding.	Weekly samples of shoreline water at a hatchery intake on Grand Isle, Louisiana, are collected to include analysis of hydrocarbons and dispersants.	Ecosystem health and indicators
University of West Florida	Monitoring of dissolved organic matter and other water quality parameters in coastal areas of Pensacola. No funding.	Biweekly samples collected from five coastal stations around Pensacola will be analyzed for dissolved inorganic nutrients, chlorophyll a, dissolved organic carbon, and (possibly) dissolved organic nitrogen.	Ecosystem health and indicators
University of New Orleans	Assess potential exacerbation of oyster mortality due to the parasite *Perkinsus marinus* due to the oil spill contamination. No funding.	Using long-term baseline disease levels collected by a community of scientists, managers, and oyster growers, potential impact of the oil spill on oyster mortality by this parasite will be explored.	Ecosystem health and indicators
Dauphin Island Sea Lab	Assess the effects of the oil spill on the nursery role of marshes in the Northern Gulf of Mexico. Funding by NOAA, Northern Gulf Institute, and Alabama Department of Conservation and Natural Resources	Using comparisons to pre-spill data, the impact of the oil spill on the abundance, diversity, and productivity of marine invertebrates and vertebrates in coastal marshes of the Northern Gulf of Mexico will be assessed.	Ecosystem health and indicators

	(ADCNR).		
Louisiana State University	Investigate the effect of the oil spill on growth and mortality of brown shrimp and blue crab. Funding by Louisiana Sea Grant.	Using monthly sampling in salt marshes and open bays in coastal Louisiana, an evaluation of the impact of the oil spill on brown shrimp and blue crab will be conducted.	Ecosystem health and indicators
Louisiana State University	Assess the effects of water column and oyster and blue crab body burdens of PAHs on their sublethal responses. No funding.	Samples of PAHs, blue crabs, and oysters will be collected and compared with past collected data to look at impacts of the oil spill due to PAHs to investigate anabolic capacity and apopstasis status of both species.	Ecosystem health and indicators
University of West Florida	Examination of reed fish ecology on the NW Florida shelf. Funding by Florida Fish and Wildlife Research Institute, NOAA/National Marine Fisheries Service.	Video sampling with ROV is conducted to examine reef fish community and size structure at natural and artificial reef sites across the shelf. Fish are then sampled to collect stomach otolith and muscle tissue samples for analysis.	Ecosystem health and indicators
Cooperative Institute for Ocean Exploration, Research and Technology	Assess the impact of the oil spill on Florida's mesophilic and deep water ecosystems. Funding by NOAA/Office of Oceanic Atmospheric Research.	Post oil spill, but prior to significant impact, CIOERT is conducting a rapid response, multidisciplinary, multi-institutional expedition to assess the impacts of the oil spill on Florida's mesophilic and deep water ecosystems.	Ecosystem health and indicators
The University of Southern Mississippi Gulf Coast Research Laboratory	Assess genetic changes induced by the oil contamination in populations of coastal organisms. No funding.	This study will explore the effects of chemical contamination on genetic variation in affected populations by generated mutations through mutagenic effects resulting in loss of genetic diversity and by inducing directional genetic change via selection and adaptation to the contaminated environment.	Ecosystem health and indicators
Mississippi State University	Visualize and detect stress-induced impacts of the oil spill on sensitive marshlands along the Gulf using hyperspectral image analysis. No Funding.	Hyperspectral imagery will be used to look at simple vegetation indices, looking at broad spectral characteristics as well as fine-scale spectral characteristics, analyzing the remotely sensed imagery over time to do before/after analysis.	Ecosystem health and indicators
Louisiana State University	Exploring the interactive effects of petroleum contamination and hurricanes on coastal biodiversity transitions. Funding by National Institute for Climate Change Research, Coastal Restoration and Enhancement through Science and Technology, and Undergraduate Research Opportunity Program.	Using plots installed at 1-2 m change in elevation from coastal marine inshore submerged seagrasses and waters' edge salt marches to high biodiversity upland terrestrial pine savannas used in past studies to study the effects of hurricanes Ivan and Katrina, the effects and responses to contamination by oil brought when hurricanes (storm surges) cross the Gulf of Mexico.	Ecosystem health and indicators
University of North Carolina at Wilmington	Better understand the ecology, biology, distribution, and derivation of deep sea corals/hardgrounds, and compare community composition, fauna/habitat linkage, genetic structures, and energetics across latitudes, habitat types, depth zones and regions. Funded by USGS.	The approach is the use of a combination of focused studies and *in situ* experiments and limited exploration and description of sites throughout the Gulf of Mexico. Topical research areas include physical oceanography, trophodynamics, genetics, microbiology, benthic ecology, and geochemistry.	Ecosystem health and indicators
Louisiana State University	Microbial species and community structure as indicators of oil spill recovery and restoration. No funding.	This research will look at using quantitative relations of the proportion of *Acinetobacter* sp. in the microbial community during remediation and recovery in laboratory microcosms and	Ecosystem health and indicators

		develop DNA qPCR methods to evaluate contamination and recovery.	
University of Southern Mississippi	Oil spill effects of metal and nutrient distributions. Funding by NSF.	Both direct and indirect effects of the oil spill on metal and nutrient distributions.	Ecosystem health and indicators
USM/GCRL	Monitoring of phytoplankton to monitor impacts and recovery. No funding.	Goal is to determine response to immediate and long-term effects of the oil spill in the eastern Mississippi Sound.	Ecosystem health and indicators
University of Mississippi	Assessing the impact of oil spill contamination on the physiological responses of seagrasses in the northern Gulf of Mexico and Florida. No funding.	Measuring PAH levels in seagrasses and sediments and characterizing protein-level responses using proteomics and direct measurements of stress protein expression levels.	Ecosystem health and indicators
University of West Florida	Comparison of reef fish community structure and dynamics at artificial reefs in Florida to determine the impact of the oil spill. No funding.	Using data from 27 artificial reef sites located 25-35 km off the coast of Pensacola, will serve as an index of multi-year variability to assess the potential effects of oil on the shelf.	Ecosystem health and indicators
Auburn University	Provide a baseline for fish samples in the Mobile-Tensaw River Delta for comparison to oil impacted waters. ADCNR, EPA, Mississippi-Alabama Sea Grant Consortium, Alabama Agricultural Station.	Data were collected from 6-8 sites during 2002-2009 in the Mobile-Tensaw River Delta in coastal Alabama that provide a baseline dataset for comparison with post-oil spill.	Ecosystem health and indicators
Texas A&M University	Using dissolved organic matter as a proxy for changes in the overall cycling of organic carbon in coastal marshes as impacted by the oil spill. NSF.	Compositional changes of DOM in marshes dying from oil contamination will serve as a proxy that integrates the overall biogeochemical changes in organic matter cycling of Louisianan marshes.	Ecosystem health and indicators
Texas A&M University	Validate advance reproductive biomarkers to conduct comparison in exposed systems. No funding.	Techniques will be used to assess reproductive toxicity and visibility in *Crassostrea virginica* such as sperm chromatin structure assay, comet assay, acrosome integrity assay, morphology, and computerized motility assessment to see how environmental conditions influence reproductive parameters in the exposed areas.	Ecosystem health and indicators
University of Mississippi	Quantify water and sediment-associated PAHs to monitor development defects and ethoxyresorufin-*o*-deethylase activity. No funding.	Will sample from 10 sites between Gulfport and Mobile that have been monitored since hurricane Katrina to determine water and sediment PAH effect on exposure.	Ecosystem health and indicators
Louisiana State University	Explore the relationship between seawater PAH exposure in Barataria Bay, Louisiana, and PAH body burdens in mollusks and blue crabs. NOAA.	Using passive samplers, PAHs were monitored in the bay prior to the impact of the oil spill. These data will serve as a baseline to study the recovery of oyster and blue crab populations.	Ecosystem health and indicators
Texas A&M University	Use UV excitation emission for assessing very low levels of hydrocarbons from oil recovered from near the blowout. No funding.	Dissolved and suspended hydrocarbon concentrations (PAHs and other aromatics) in blowout water.	Oil spill modeling and tracking
CEDB-UWF	Monitor water quality of Florida beaches. No funding.	Water samples from Escambia, Santa Rosa, and Okaloosa Counties are being monitored for dissolved hydrocarbons for use by beach officials.	Oil spill modeling and tracking
Geosystems Research Institute-Mississippi State University	Development of a GIS decision-making framework to assist the coordination of research activities in multiple levels of coastal ecosystems.	A pilot version of an interactive tool to geographically support decision-making based on the hierarchical multiscale research undertaken by the NGI/Natural	Oil spill modeling and tracking

	Funding by NOAA.	Systems team. The framework will be designed for collaborative involvement, scenario evaluation, and comparative analysis.	
University of Southern Mississippi	Better define the spatial heterogeneity of coastal hypoxia events in the Mississippi Sound and Bight. No funding.	Spatial heterogeneity of coastal hypoxia events will be explored by profiling the salient oceanographic parameters with high geographic resolution in the larger context of coast ecology and hydrologic optics monitoring.	Oil spill modeling and tracking
COAPS-FSU	Modeling of surface oil trajectories. No funding.	Using the Gulf of Mexico 1/25 degree HYCOM surface currents and forecast wind products concurrently with SAR-derived imagery to develop objective metrics for evaluating model forecasts of surface oil trajectories.	Oil spill modeling and tracking
CMS-USF	Oil spill modeling, tracking, and monitoring. No funding.	Using an ensemble of six different models to track the oil spill. Predictions are compared with observation from satellite imagery and used by NOAA in their forecasts.	Oil spill modeling and tracking
University of Southern Florida	Oil tracking and impact assessment using satellite. No funding.	Satellite monitoring began on the first day of the spill to provide surface oil location and major circulation features. Primary use is for State agencies and research groups.	Oil spill modeling and tracking
Earth Scan Laboratory	Develop new products and detailed maps showing arrival times of oil in key coastal regions. Funding unknown.	Using earth observing systems, including MODIS, AVHRR, GOES, and Radar systems, will develop additional products by integrating data. Project is actively looking for collaboration.	Oil spill modeling and tracking
ROFFS	Using satellite monitoring to map the distribution and movement of the oil spill. Funded by ROFFS, NOAA/OAR.	Using host U.S. (NOAA and NASA) and European (ESA) satellites to visualize the movement of the oil.	Oil spill modeling and tracking
Louisiana State University	Investigate the acute toxicity of a primary oil dispersant to biologic endpoints across a range of salinities. Funded by NOAA and Louisiana Sea Grant.	Studying the toxicity of the anionic surfactant dioctyl sodium sulfosuccinate to eggs and large and juvenile Gulf killifish at varying salinities.	Toxicology, dispersants
Organization Unknown	Develop best management practices for cost effective biodegradation of spill-derived petroleum hydrocarbons. No funding.	Land treatment systems developed by the petroleum industry for disposal of refinery-derived wastewater treatment sludge to support natural and engineered microbial breakdown is being explored as a BMP.	Unknown
Unknown	Conduct pre-impact assessment of oil on deep water and mesophotic coral reefs. Funded by NOAA/OAR.	Conducting a rapid response, multidisciplinary, multi-institutional expedition to assess the impact of the oil spill on Florida’s mesophotic and deep water ecosystems.	Unknown
Unknown	Understand the occurrence of marine snow due to the presence of oil and dispersants. Funded by NSF.	Understand the influence of oil and dispersants on the formation of natural marine snow, looking at characteristics such as composition, density, sinking velocity, fragility, etc.	Unknown

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